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Early MPT Estimation Methods: An Evaluation of the LHX Test-Bed Research Program

Volumes I and II

Horizons Technology, Inc.

for

Contracting Officer's Representative
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Research Institute for the Behavioral and Social Sciences

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The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has been a major sponsor of research efforts to develop MANPRINT methods. This report describes a program initiated in early 1985 that focused on the development and testing of analytic and predictive MANPRINT-manpower requirements methods. Since the program used LHX acquisition data in methodology development, a second goal was to apply prototype products in support of the LHX Program Manager efforts to analyze LHX manpower requirements. The total effort resulted in seven interrelated projects, including the development of three software tools--the Transition Training model, the Electronic Aids to Maintenance (EAM) model, and the Manpower and Mission Capability (MANCAP) model. The Transition Training model is a scheduling tool that estimates the training resources required and average unit readiness downtime given a particular unit training schedule. The EAM is a spreadsheet-based Administrative and Logistics Delay Time model that incorporates potential BIT failures in the failure and

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repair sequence, allowing for the examination of the impact of EAM performance deficiencies on LHX aircraft availability. The MANCAP model is a computer-based model that estimates mission capability of a weapon system based upon weapon system characteristics, operating organization characteristics, and mission performance profiles.

The full report is incorporated in two volumes. The first provides a review of the seven project activities and results and discusses lessons learned that can be relevant to future MANPRINT methodology development efforts. The second volume presents copies of the three software models/tools developed under this effort and instructions for their use.

FOREWORD

In 1984, the U.S. Army initiated its MANPRINT (Manpower and Personnel Integration) program. The objective of the MANPRINT program is to increase the effectiveness and reduce the life cycle cost of materiel systems by considering the "soldier in the loop" early in the system acquisition process. A major challenge facing the MANPRINT initiative has been the development of methods for conducting analyses that provide realistic estimates of the impact of MANPRINT factors on system performance and costs.

The research described in this report was started in early 1985. It represents one of the U.S. Army Research Institute's (ARI) early efforts to develop and test critically needed analytic methods that could be used by the Army Materiel Command and the Training and Doctrine Command combat development communities to conduct MANPRINT analyses prior to major system acquisition. A second goal of the project was to provide analytic support to the LHX (Light Helicopter Experimental) Program Manager's Office (PMO's) and the U.S. Army Aviation Center (USAAVNC) through the application of the prototype methods to the LHX.

The research included a series of six interrelated projects:

- LHX Organizational Modeling
- Two-Level Maintenance Concept
- Electronic Aids to Maintenance
- Unit Training
- LHX Life Cycle Contractor-Delivered Training
- LHX MANPRINT Integration

The results of each of these projects were reported earlier in separate reports and briefings were given to the LHX PMO and USAAVNC from 1985 to 1988.

In each of these projects, the research team engaged in an iterative process of method development, application to provide analytic support to the LHX PMO and USAAVNC, and further method refinement and analysis. Throughout the program, the research team attempted to balance the demand for generic methods to analyze weapons systems with the demand for prototype models to meet the specific analytic requirements of the LHX PMO and USAAVNC.

A discussion of the efforts and analyses of the project are presented in Volume I of this report, along with a description and evaluation of the methods developed. Volume II contains copies of the three software products developed as a part of this project and includes instructions for their use. The reader should note that in reviewing the project description and related products, the LHX acquisition was selected as an illustrative

effort only and the focus of the effort was to develop methods and processes applicable not only to the LHX but to the early stages of any major system acquisition program.

EARLY MPT ESTIMATION METHODS: AN EVALUATION OF THE LHX TEST-BED RESEARCH PROGRAM

EXECUTIVE SUMMARY

Requirement:

To develop an integrated systems approach to MANPRINT, with methods that interrelate results of various processes and methods developed to address MANPRINT Manpower program concerns.

The goal of the research effort was to develop integrated methods to analyze MANPRINT manpower information. The intention was to use the LHX acquisition program as a sample program for developing processes, models, and tools that Materiel Command and the Training and Doctrine Command Combat Development communities could use to conduct MANPRINT manpower analyses early in the concept development phase of a major system acquisition program. With the use of the LHX procurement process, the research team also provided critical manpower analytical support to the LHX Program Manager's Office as an adjunct to their method development efforts.

Procedure:

The objectives of the research effort required a conceptual framework or model of MANPRINT to provide the basis for identifying critical MANPRINT manpower information requirements. The framework focused the attention of the research team on the two primary issues of system operability and supportability as they affect potential system design considerations.

From this focus, a series of six interrelated projects were conducted to develop analytic and predictive MANPRINT tools. These efforts included:

- Organizational Modeling
- Two-Level Maintenance
- Electronic Aids to Maintenance (EAM)
- Unit Training
- Life Cycle Contractor-Delivered Training
- MANPRINT Integration

In each of the projects, the research team attempted to balance the requirement of developing generic methods having valid utility across systems with the requirement to meet specific analytic needs in the LHX procurement process. All

efforts were conducted with an applied focus, however, and resulted in procedures, models, tools, and lessons learned that will be relevant to future system acquisition efforts.

Findings:

The results of the current research effort include a general structure for organizing MANPRINT information and specific prototype modeling technologies for assessing manpower requirements and efforts in a system acquisition and fielding process. Volume I of this report outlines the processes used and research efforts of the six separate activity areas of the total project.

Volume II presents the modeling software developed as a part of this effort and instructions for utilization. Products include the following:

MANCAP: A computer-based model that estimates mission capability of a weapon system based upon weapon system characteristics, operating organization characteristics, and mission performance profiles.

EAM: A spreadsheet-based model that employs data from Electronics Aids to Maintenance systems comparable to the EAM system planned for the LHX. It is a modified Administrative and Logistics Delay Time Model which incorporates potential BIT failures in the failure and repair sequence.

Unit Training: A scheduling tool that estimates the training resources required and average unit training schedule.

Utilization of Findings:

From a methodological standpoint, the overall LHX MANPRINT research program was successful in breaking new ground. The approach provides a preliminary framework for guiding the development of a comprehensive MANPRINT analysis program for major system acquisition efforts. The approach initially developed during the LHX MANPRINT research program has been successfully applied and refined in the Forward Area Air Defense System MANPRINT research program.

The MANCAP model that evolved from the LHX organizational modeling efforts has great potential as a valuable tool that can be applied to examine manpower and personnel requirements in new materiel systems. Most importantly, the model can be applied early in the concept development phase and can serve as a means by which system designers and program managers can generate and evaluate a variety of design alternatives. The model can be used to examine changes in maintenance organizational structures and

proposed mission profiles as well as changes in the system's RAM characteristics. Furthermore, the model allows the decision-makers to examine MANPRINT impacts beyond that of a single system in isolation. Manpower requirements and system performance can be examined in the context of a unit attempting to perform a specified mission. Thus, the model can be used to aid in the development of doctrine as well as to "MANPRINT" the materiel system itself.

The method developed during the unit training effort also has the potential of wide applicability. While the computer model used in the unit training project was never developed beyond an early prototype stage, it was successful in generating data considered useful by the Aviation School. The general training planning method and the computer model, if fully developed, have considerable potential in aiding in the planning of training during the fielding of new systems as well as reserve component unit training.

Other methods and the EAM computer model developed during the LHX MANPRINT research program have a somewhat more limited direct application to other system acquisition efforts. These applications were designed to answer LHX specific questions and were never developed beyond the prototype stage. While the models themselves may not be directly applicable, however, the general approaches developed in these studies are highly relevant to solving similar problems in future system acquisition programs. In addition to the actual models and methods developed during the LHX MANPRINT research program, there are a number of "lessons learned" that are relevant to future work in the development of MANPRINT methods and that are reviewed in the last section of Volume I.

EARLY MPT ESTIMATION METHODS: AN EVALUATION OF THE LHX TEST-BED RESEARCH PROGRAM, VOLUME I

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Introduction

Overview

In 1984, the U.S. Army initiated its MANPRINT (Manpower and Personnel Integration) program. The objective of the MANPRINT program was to increase the effectiveness and reduce the life-cycle cost of materiel systems by considering the "soldier in the loop" early in the system acquisition process. The Army identified six MANPRINT domains that are to be examined for each major system. The MANPRINT domains include:

- Manpower,
- Personnel,
- Training,
- Human Factors Engineering,
- System Safety, and
- Health Hazards.

A major challenge facing the MANPRINT initiative was, and continues to be, the development of methods for conducting analyses that provide realistic, early-on estimates of the impact of MANPRINT factors on system performance and system costs.

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has been a major sponsor of research efforts to develop MANPRINT methods. The research described in this report represents one of ARI's early efforts to conduct applied research supporting the MANPRINT initiative. The LHX (Light Helicopter Experimental) MANPRINT Test-Bed Research Program was initiated in late 1985. The program had two primary objectives: the first objective was to develop and test analytic methods that could be used by the Army Materiel Command and the Training and Doctrine Command (TRADOC) Combat Development communities to conduct MANPRINT analyses early in the concept development phase of a major system acquisition program; the second objective was to provide analytic support to the LHX Program Manager's (PM's) office through the application of the prototype methods to the LHX.

The emphasis placed on both objectives of the LHX research effort created the requirement to conduct an applied research program. The program ultimately included a series of seven interrelated projects. In each of these projects, the research team engaged in an iterative process of method development and application to provide analytic support to the LHX PM, and further method refinement and analysis. Throughout the program, the research team attempted to balance the demands to design generic methods that could be applied to any major weapon system

with the requirement to develop prototype models to meet the specific analytic requirements of the LHX PM.

Background

When the LHX research program was initiated, the LHX system acquisition program had very high visibility within the Army. The program was very large in terms of potential costs, and its success was viewed as highly dependent on its ability to reduce manpower requirements through the application of high technology. The proponents of the LHX indicated that emerging technology and superior design would enable the Army to field a single pilot aircraft which could meet a variety of Army mission requirements. Furthermore, changes in the nature of maintenance technology, electronic aids to maintenance (EAM), and movement to a two-level maintenance (2LM) structure were offered as means by which the Army would further reduce manpower requirements on the maintainer and support side of the LHX. The visibility of the LHX program and the well-articulated goals of reducing manpower, personnel and training (MPT) through the use of high technology made the LHX a natural opportunity for testing the development of new MANPRINT early estimation methods.

The relationships among Horizons Technology, Incorporated's (HTI's) early estimation research efforts is depicted in Figure 1. A number of important things about Figure 1 are worth mentioning to provide the reader with a context for the sections which follow. While the goal of all six projects was to perform quality applied research, the research team approached ARI versus LHX PM initiated efforts with a slightly different orientation. The latter were typified by requests for answers to questions specific to the LHX, sometimes in the absence of methods developed to provide those answers. Requests initiated from ARI, on the other hand, were typified by an opportunity to perform generic research and development, the products from which would extend outside the scope of the LHX program.

Another important aspect of the LHX research program shown on Figure 1, is that the individual efforts appear to be somewhat fragmented. This is partially true. While projects such as Unit Training were not directly related to any of the other projects, all projects were related in the sense that they supported the LHX MANPRINT research program.

The results of the analyses conducted specifically for the LHX have been provided to members of the LHX community through a series of briefings and research reports. The purpose of this report is to provide members of the research community with a description and evaluation of the methods developed during the LHX MANPRINT research program. Results specific to the LHX program will be discussed for illustrative purposes only. The focus of this report is on methodological issues and lessons learned in attempts to apply MANPRINT analysis methods in the early stages of a major system acquisition program.

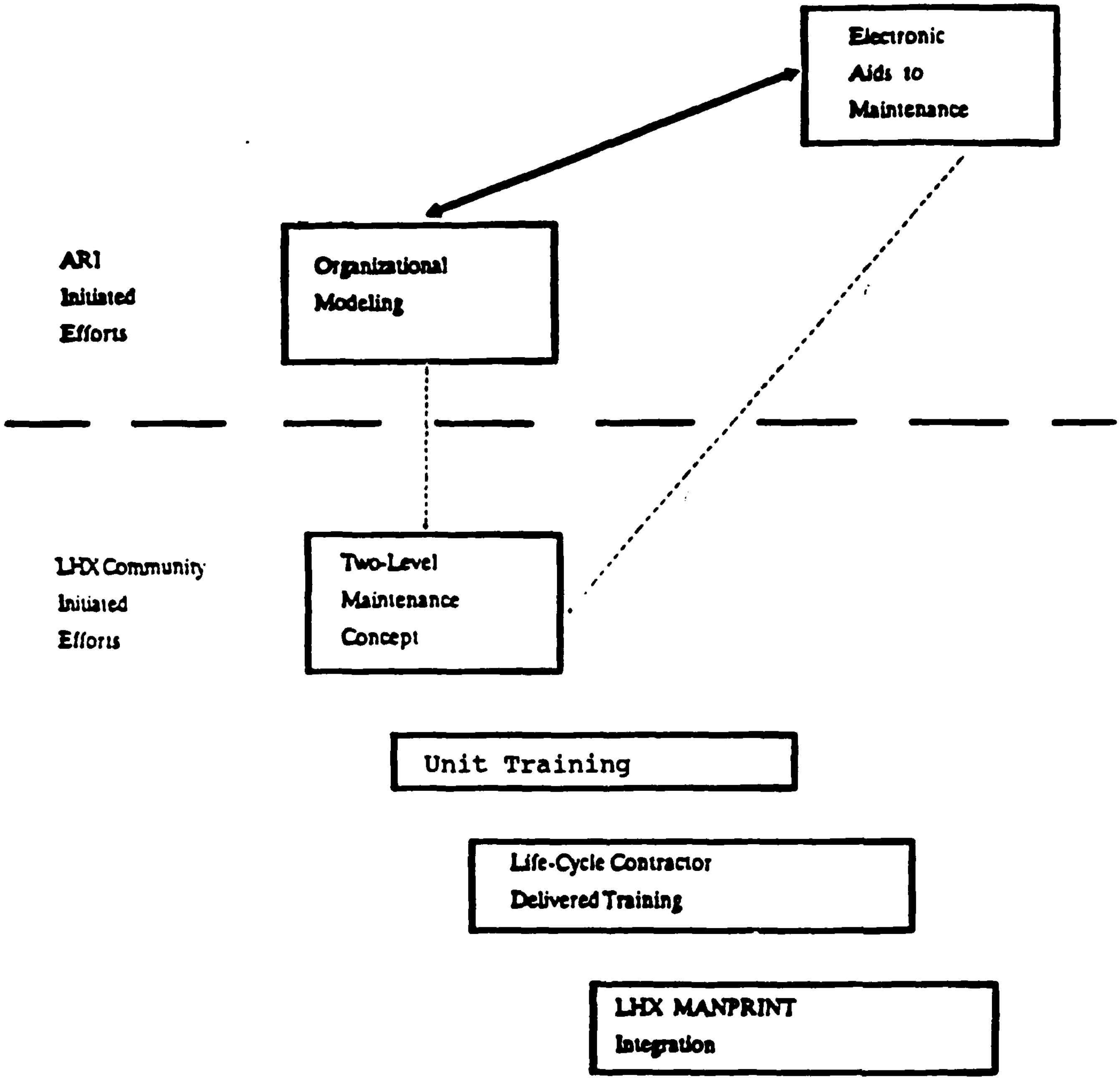


Figure 1. Relationship among research efforts.

Organization of the Report

The report is organized into two volumes. This is the first volume and includes eight major sections which provide an overview of the evolution and final structure of the major methodological accomplishments and lessons learned in the LHX program. The software, model outputs and instructions for application of the three major computer models developed during the LHX research program are provided in Volume II of the report.

The first major section of this volume is entitled "Manprint Conceptual Framework" and provides a brief discussion of the background of the Army's MANPRINT initiative and a discussion of the rationale for the LHX research effort. This rationale includes a more detailed discussion of the objectives of the LHX MANPRINT test-bed. It also provides a detailed discussion of the conceptual framework underlying the entire LHX MANPRINT program. This framework played a major role in shaping the research approach and structures of the methods developed in the LHX research project. An understanding of the biases inherent in the conceptual framework is required to appreciate fully later discussions evaluating the methods developed in the program.

The next section, "The LHX Organizational Modeling Research Program," is the first section in a series of sections describing the individual research projects. It describes the LHX organizational method research effort that resulted in development of the manpower and mission capability (MANCAP) model and represents the most significant portion of the LHX program. The research was conducted in three phases. In Phase I, it was demonstrated that a top-down method of analysis that assessed manpower in terms of its contribution to mission capability was feasible. Specifically, Phase I resulted in a prototype model of the mission operation and attendant maintenance and supply activities of a company-size unit. In Phase II, a new computer model which could be applied to a division-size organization was developed and applied to the LHX. The MANCAP model that utilized predecessor system data was the major product that resulted from the Phase I and II research. In Phase III, the Apple MacIntosh-based Phase II MANCAP model was transformed to run on an IBM compatible personnel computer (PC).

The third major section, "MPT Implications of the LHX Two-Level Maintenance Concept," examines the methodological issues encountered in conducting a research effort to define and evaluate a 2LM organization for the LHX. The discussion critically reviews the results of the research effort and provides several lessons learned regarding attempts to conduct MANPRINT analyses prior to complete development of system support requirements.

Next is "An Analysis of Electronic Aids to Maintenance for the LHX." Performance of the EAM was identified by ARI as a key LHX manpower and personnel requirement. Past experience within

the Department of Defense (DoD) indicated that built-in test/ built-in test equipment (BIT/BITE) typically did not reach the performance goals established for that technology. Further, EAM technology often created new manpower problems rather than reducing maintenance manpower requirements. This experience within DoD was the impetus for the analysis of EAM for the LHX. The research effort discussed in this section included a review of technical and military literature, collection of data on the performance of EAM in existing Army systems, and development of a model to examine performance impacts of projected EAM performance in the LHX system.

The fifth section, "Unit Training," describes the development and application of a computer model for planning unit training and analyzing training resource requirements during the fielding of a new weapon system. The discussion of this research effort focuses on the development of modular models and strategies for acquiring and reducing training resources data.

The next section, "Analysis of Life Cycle Contractor Delivered Training (LCCDT) for Military Aircrew and Aircraft Maintainers," describes a second research effort in the LHX training domain. This project examined LCCDT for LHX operators and maintainers as an alternative training method. The discussion of the effort focuses on the method only. The product of this research effort was the development of a trade-off analysis method that, when applied to the LHX, may provide data that is useful in comparing training alternatives. As long as the LHX procurement is active, the distribution of the detailed results of the analyses is limited to U.S. Government Agencies and their contractors.

The seventh section, "LHX MANPRINT Integration," describes an attempt to develop a method for integrating MANPRINT issues and data in preparation for an Army Systems Acquisition Review Council (ASARC) decision briefing. The description of the problems and methodological issues related to this research effort provide an introduction to the discussion of general methodological lessons learned from the LHX MANPRINT research program.

The final section, "Evaluation of the LHX MANPRINT Research Program and Lessons Learned for Future MANPRINT Research Applications," provides a summary of the LHX research program objectives, accomplishments, and problems. A detailed discussion of lessons learned and the implications of these lessons for future method development and application to LHX and other systems is provided.

MANPRINT Conceptual Framework

The Army MANPRINT Initiative

Over the past several decades, weapons systems have become considerably more complex. Increasing applications of so called "high technology" are resulting in the development and deployment of systems that are intrinsically different from those of previous generations. High technology enables the development of weapon systems that are more capable than their predecessors by several orders of magnitude. Such capabilities are not, however, acquired without a price. Unless considerable care is taken during development, these systems tend to be more difficult to operate and maintain than are their predecessors.

Along with increasing sophistication in hardware technology, the demands placed upon the personnel who must operate, maintain, and support these new systems have risen significantly. The role of human operators in this new class of high technology systems has tended to change from that of an operator in the traditional sense to one more akin to what might be termed a "system manager." Complexity in operations and maintenance has also resulted in a change in the pattern of required human capabilities. The new class of systems tends to place a premium on operator and maintainer cognitive abilities (e.g., information processing, decision making, etc.) and rely to a lesser extent on human sensory and psychomotor capabilities, and physical abilities. For certain classes of systems, and considering only individual weapon systems performance (a necessary but not sufficient condition for military success), human cognitive abilities are becoming a critical determinant of overall system performance, and thus represent a major aspect of developmental risk.

The growing complexity of military systems and their operating environments has necessitated an approach to systems development that takes personnel issues into full account. It is no longer prudent to design a system and then to worry about manning it. The developmental risks associated with such an approach are simply too great. Often, the result can be an inoperable system: a system that cannot be used for its designed purpose regardless of the burden that a developer might be willing to bear. In their discussion of reverse engineering studies of the M1 tank (Marcus & Kaplan, 1984) and the multiple launch rocket system (Arabian, Hartel, Kaplan, Marcus, & Promisel, 1984), the authors identified problem areas in the acquisition process and reaffirmed the need for change in materiel systems acquisition philosophy. The lesson of the past several decades is that increasingly complex systems will often entail additional complexity in human operator, maintainer, and support requirements. What must be done, however, is to keep the rate of increase in human performance complexity within manageable bounds.

The objective of the Army's MANPRINT initiative is to address the problem cited above by constraining military system design to match available personnel resources (numbers, abilities, and training). Officially, the MANPRINT program is concerned with imposing the full range of human factors engineering, manpower, personnel, training, system safety, and health hazards considerations over the weapons system acquisition process from concept exploration through fielding. Stripped to its essence, the MANPRINT initiative requires system developers to address three basic personnel-related issues:

1. What performance is required of human operators, maintainers, and support personnel, and are these performance demands reasonable?

2. Is the proposed system concept operable and able to be used with representative humans "in the loop" for its designed purpose (both performance levels and range of operating environments)?

3. What are the proposed system's MPT requirements, and can these requirements be accommodated within available MPT assets?

In addition to the substantive issues cited above, the MANPRINT initiative imposes two additional requirements: system developers must address personnel issues early and they must do so in an integrated fashion. Everyone concerned with military system development has been made well aware of the rationale for addressing personnel issues early. Many of the decisions that will have a later impact upon a weapon's performance and personnel-related support costs are made very early during its life. Hence, system developers must consider the personnel-related consequences of a proposed concept before "metal is bent." Early consideration of personnel issues is a major contributor to developmental risk reduction.

The MANPRINT initiative also requires system developers to approach the treatment of personnel issues within an integrated framework. Under MANPRINT, the traditional "stovepiped" approach to system development can no longer be permitted. Doctrine, materiel design, employment concepts, logistics support considerations, and personnel factors are highly interactive with system performance and cost. To be approached successfully and thus to contribute to risk reduction, a system's MANPRINT program cannot be carried out in isolation from other aspects of the developmental effort, most notably materiel design and integrated logistics support (ILS).

The need for an integrated systems approach to the MANPRINT analysis process was further reinforced by the Army's Vice Chief of Staff, General Thurman, in the early 1980s when he emphasized that the Army fields units, not just materiel systems. The point attributed to the Vice Chief of Staff is that changes in a

materiel system normally cause changes in the manner in which units organize and train for combat missions. Thus, to provide a comprehensive treatment of MANPRINT issues requires methods which translate changes in materiel system design into changes in organization design and training.

HTI's MANPRINT Approach

The three basic personnel issues noted in the section above provided the conceptual point of departure for HTI's approach to MANPRINT analyses for the LHX. HTI developed a conceptual framework for conducting MANPRINT analyses which is currently referred to as the systems integration MANPRINT model (SIMM). In short form, the three issues are: (1) performance requirements, (2) system operability, and (3) MPT affordability. The six technical domains comprising the MANPRINT initiative line up directly with two of these three issues. Human factors engineering (HFE), system safety, and health hazards are subsumed under system operability; manpower, personnel and training are treated under MPT affordability. Concurrently, all areas are affected by system performance requirements. Addressing the six MANPRINT technical domains as sub-issues under a more encompassing set of decision issues has the positive effect of fostering the goal of an integrated MANPRINT program. Moreover, two of the basic issues, system operability and MPT affordability, can be related easily to program elements that MANPRINT must influence if the initiative is to be successful: materiel design (i.e., operational suitability) and ILS. MPT affordability traditionally has been treated as an ILS issue during system development and the source selection process.

The SIMM has the effect of pulling the six technical MANPRINT domains together into a framework that is consistent with the system development process. At the same time, the three basic MANPRINT issues noted earlier are addressed in a straightforward and unambiguous manner. An effective MANPRINT program cannot be carried out by addressing each of the six domains separately. Some means of achieving goal-oriented, conceptual integration, or a way of "weaving the MANPRINT threads into cloth," is required. The SIMM is an effective means of fostering this integration. The SIMM itself is structured into eight separate steps listed below. A schematic of the steps comprising the SIMM and their relationship to each other is provided as Figure 2.

1. MANPRINT Front-End Systems Analyses,

2. Human Factors Engineering Analyses,

3. Health Hazards Assessments,

4. System Safety Assessments,

5. MANPRINT Supportability Analyses,

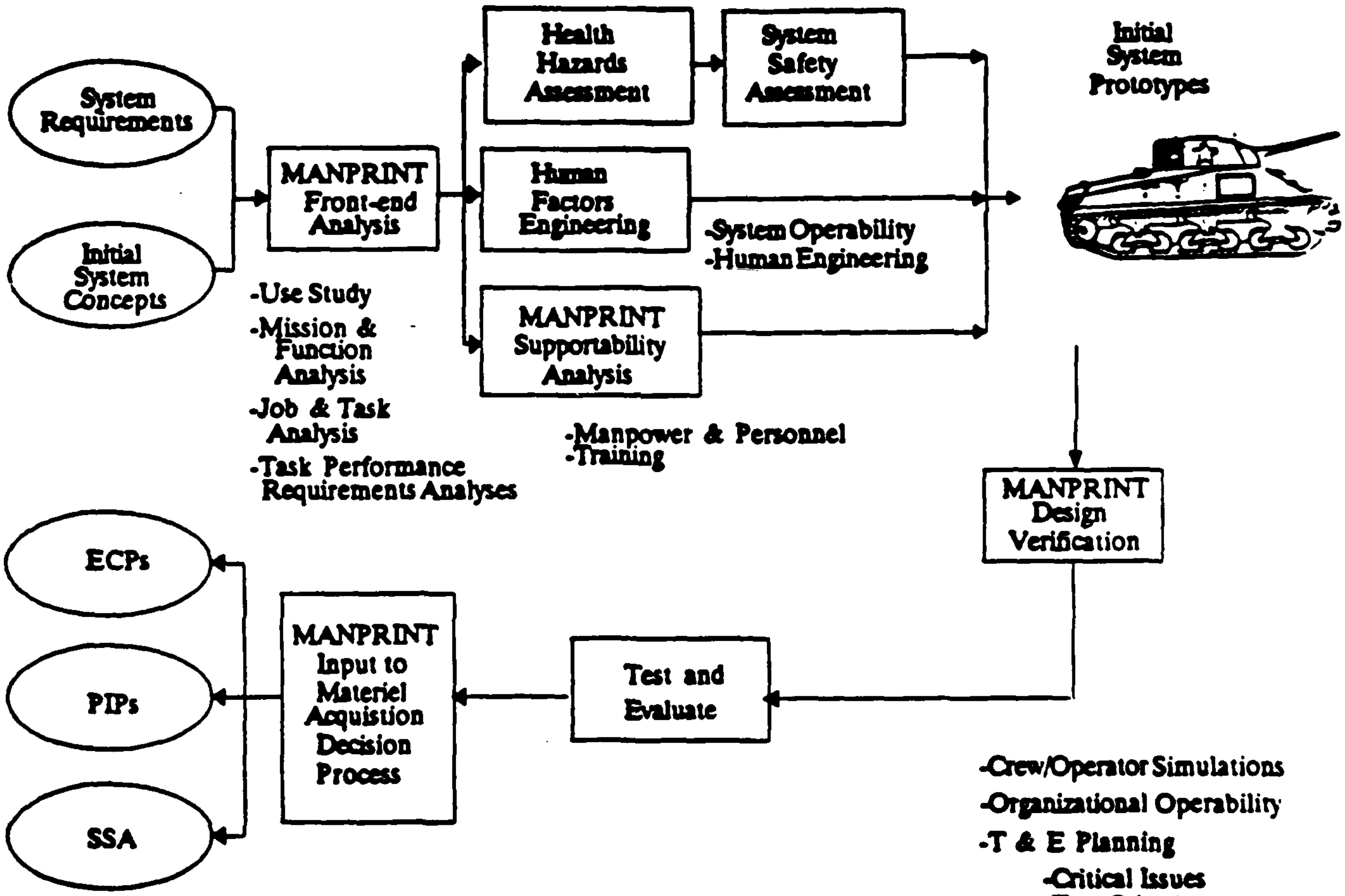


Figure 2. The systems integration MANPRINT model.

6. MANPRINT Design Verification,

7. Test and Evaluation, and

8. MANPRINT Input to the Materiel Acquisition Decision Process.

Each step comprising the SIMM is described briefly in the subsections to follow.

Step 1 - MANPRINT Front-End Systems Analyses

One of the requirements of MANPRINT, setting it apart from earlier personnel-related initiatives, concerns an up-front definition of performances and standards.

The procedures, techniques and approaches used to generate this definition collectively make up a process called a front-end analysis (FEA). This term has evolved from the recognition that a specific, baseline information collection phase must be conducted in order to have complete, valid and consistent data available for later planning, research, test and design efforts. As the need for a FEA phase has been acknowledged as critical to productive MANPRINT efforts, specific supportive techniques have been developed and adopted (e.g., HARDMAN (Hardware versus Manpower) comparability analysis method and HARDMAN-like technologies).

The first step in the SIMM approach to FEA is to define the system's operating environment--the conduct of what the Army refers to as a use study. Following the use study, the system's missions, functions, and subfunctions are determined. Based on these results, operator, maintainer, and support tasks, subtasks, and task elements are identified. Conditions data are then provided and initial function, subfunction, and task performance standards are estimated. As needed, specific techniques are adapted and applied to insure all critical data items are examined.

It is desirable for this approach to FEA be coordinated with the logistics support analysis and, to the extent possible, that the results be used to support both the HFE and MANPRINT supportability analyses to follow. Given a common information base, it is considerably easier to integrate the results of both sets of analyses and support the actions that take place during the MANPRINT design verification step.

Step 2 - Human Factors Engineering Analyses

In recent years, and particularly within the context of MANPRINT, the term HFE has come to imply considerably more than traditional human engineering. Increasingly, the term HFE implies both human engineering and, for lack of a better term, what will be referred to as system operability assessment, which

determines the performance potential of a weapon system considering available operators, maintainers, and support personnel (see Army Regulation [AR] 602-1 and MIL-H-46855B). Human engineering, on the other hand, is being viewed increasingly as synonymous with the discipline of ergonomics, which is defined as properly fitting humans into a particular design concept.

The primary difference between the two aspects of HFE is one of focus. System operability is concerned with macro-level issues pertaining to the viability of the humans' role in a system (i.e., human-machine systems integration). Human engineering is concerned with defining an appropriate man-machine interface once the humans' role within the broader system concept has been defined. Both aspects of HFE are essential to a comprehensive human factors program. In recognition of the dual nature of HFE, the SIMM's HFE analyses are conducted in two distinct but related sub-steps, one concerned with system operability and the other concerned with traditional human engineering.

As noted above, the basic issue to be addressed under system operability is the performance potential of a proposed system with humans in-the-loop. At the individual operator and crew level, operability is established through analyses such as operational sequence diagraming, function or task time-lining, workload predictions, and operator and crew simulations. Other issues related to operability concern the viability of proposed maintenance and support concepts within the anticipated usage environment. (Note that such analyses represent an extension of the operability notion from a single weapons system to the unit level.) Regardless of the level at which the operability analyses are focused, it is essential that it be demonstrated early on that a proposed system can be employed as intended using personnel representative of the anticipated target population. A comprehensive system operability program initiated early on is a major contributor to risk reduction during system development.

Actions subsumed under the topic of human engineering are concerned with insuring that equipment design and job procedures are structured to accommodate human physical, sensory, psychomotor, and anthropometric characteristics. In most situations, systems and job procedures are designed in accordance with established human engineering guidelines (e.g., MIL-STD-1472C). Later, during developmental and operational testing, system prototypes are evaluated to verify compliance with established standards.

<u>Step 3 - Health Hazards Assessments</u>

The objective of the health hazards portion of a system's MANPRINT program is to review proposed design concepts to insure that they pose no threat to operator or maintainer health. Issues that are addressed typically in this regard include noise

levels; toxic missile, gun, battery, or coolant fluids or gases; and the effects of various forms of radiation (e.g., microwave, radio frequency, laser, etc.) upon crew members. The health hazards review is performed usually as system prototypes are constructed and continued during developmental and operational testing. It should be noted that operational testing of system prototypes cannot commence until an initial health hazards and safety release has been obtained.

<u>Step 4 - System Safety Assessments</u>

The objective of the system safety review is similar to that of the heath hazards assessment: The Army does not want to field a system that poses unnecessary dangers to operations, maintenance, or support personnel. Issues that are reviewed typically in this regard include electric shock, uncommanded gun or missile fire, and accidental turret motion, to name several.

The primary distinction between a health hazard and a safety issue is one of suddenness. If the problem results in a delayed onset or slow deterioration in operator, maintainer, or support person well-being, it is defined as a health hazard; if the problem results in a sudden injury, it is defined as a safety issue.

<u>Step 5 - MANPRINT Supportability Analyses</u>

The Supportability aspect of MANPRINT concerns the Army's ability to provide the MPT resources necessary to achieve desired performance levels for a given equipment configuration and usage concept. Under the SIMM, supportability is addressed in two separate but interrelated steps: 1) manpower and personnel, and 2) training. It should be noted that the MANPRINT supportability step, because of its concern for MPT, should be associated closely with the system's ILS program.

<u>Manpower and Personnel</u>. For most procurement actions, system developers are constrained to "living within the footprint" of a predecessor system. This means that a system must not require more MPT resources than are allocated to predecessor systems. In fact, it is desirable to achieve MPT savings when possible.

In the manpower and personnel domain, the footprint mandate requires that a proposed system must not require more operations, maintenance, or support personnel than predecessors and that the personnel assigned to the new system must be drawn from a designated military occupational specialty (MOS) pool (often that of a predecessor). The system must not require higher ability personnel for required performance levels to be met.

The objective of the manpower and personnel analyses is to determine the manpower and personnel characteristics necessary to reach desired levels of system performance. These requirements

also must be compared with the supply of manpower and personnel assets expected to be available to man the proposed system.

Training. Once a suitable MOS structure has been determined and the desired capabilities of MOS holders identified, the second issue under MANPRINT supportability is training. In this regard, it must be determined whether the training system likely to be in place when the hardware "hits the field" will have the capability to prepare the target population to meet performance requirements. Training requirements are established through an analysis of the training needs of the proposed system and a comparison of these requirements with existing and planned training capabilities. The performance obtainable within stated training limits (e.g., time, media, method, etc.), with materiel design, manpower, and personnel as givens, is estimated and cost-effective solutions to potential performance "gaps" identified. Under the SIMM concept, training is not to be regarded as a universal means of remediating performance deficiencies after design, manpower, and personnel concepts have been fixed.

There is an obvious relationship between the operability aspects of the HFE analyses and the MANPRINT supportability analyses described in the current section. These analyses have been separated conceptually for practical reasons, and because the two types of analyses are often separated temporally and organizationally during the acquisition process.

As a practical matter, one must often proceed by first establishing that a system concept is operable. Operability-oriented analyses are performed under various, often implicit, assumptions regarding MPT capabilities. As a second step, the MPT resources underlying operability are estimated. If these resource estimates are within limits, the analysis is concluded. On the other hand, if the MPT resources judged necessary to provide an operable system are outside of the established footprint, then a tentative statement regarding the possible impacts on system performance of using fewer MPT assets is made. Determining the actual extent of the performance decrement during operational test and evaluation is recommended. The limits of current MPT technology and data availability early on during system development provide the rationale for this somewhat conservative approach.

Step 6 - MANPRINT Design Verification

The analyses comprising the first five steps of the SIMM are intended to be performed as the system is being developed. Results from these analyses are used as formative input to the final design concept. Once a final design concept has been selected (i.e., the design freeze), MANPRINT design verification is initiated. The objective of the design verification step is to establish that the MANPRINT concept for a proposed system will result in forecasted performance levels. Design verification is carried out usually in two substeps: analytical verification and

empirical verification. Analytical verification of the MANPRINT concept represents an extension of the operability analyses. Recall that in the operability analyses, system performance with humans in-the-loop is investigated, but primarily in a piecemeal and often static mode. During the analytical portion of design verification, these earlier analyses are extended through a series of integrated, dynamic simulations intended to establish a system's performance potential further. Additional analytic exercises directed at establishing the viability of proposed maintenance and support concepts are often conducted in parallel with the operations-oriented analyses.

Analytical considerations aside, the acid test of a proposed MANPRINT concept is system performance in a combat or near-combat environment. This constitutes empirical verification of the system's MANPRINT concept. During system acquisition, empirical verification is conducted usually within the context of developmental and operational testing. For such verification to be meaningful, however, test plans must reflect areas of uncertainty encountered during the conduct of MANPRINT analyses. Furthermore, test standards must reflect system performance criteria. Planning the MANPRINT portions of test and evaluation is done as part of the design verification step. Actual empirical verification of the system's MANPRINT concept is then conducted as part of the test and evaluation program.

Step 7 - Test and Evaluation

During test and evaluation, empirical data regarding system performance are obtained. From a MANPRINT perspective, the basic issue to be resolved during test and evaluation is summarized as, "Can this man in this organization with this training use this equipment under these conditions to perform these tasks to these standards?" Personnel requirements, training issues, and system operability will have been addressed and performance and supportability estimates made during the preceding analyses. Developmental and operational testing provides the "proof of the performance pudding," so to speak. Testing provides empirical evidence that the results of the various lead-in analyses are valid. In addition, test results will indicate where modifications to design, employment, or MPT requirements are warranted.

Step 8 - MANPRINT Input to the Materiel Acquisition Decision Process

The final step in the SIMM is to integrate the results of the previous analyses and tests to provide a comprehensive and understandable summary of the MANPRINT program. Assembled results are then: (1) used to indicate necessary short-term engineering changes (i.e., input to engineering change proposals), (2) input to the system's product improvement program (i.e., mid- and long-term changes made to address MANPRINT

deficiencies), and (3) made available to the concerned source selection authority.

The previous paragraphs have provided an overview of HTI's SIMM. As noted earlier, the SIMM framework has been used to guide the various MANPRINT activities on the LHX. While the SIMM provided a sound "systems approach" to conducting MANPRINT analyses for the LHX, the realities of the LHX procurement environment required substantial modifications in the actual approach used in conducting the LHX analyses. The next section of this report describes the manner in which the conceptual approach was tailored for application to the LHX and discusses the factors which necessitated such modifications. This discussion provides valuable lessons for future researchers attempting to conduct MANPRINT analyses during the concept development phase of a major weapon system such as the LHX.

Application of the SIMM to the LHX

The SIMM provides a conceptual approach for conducting MANPRINT throughout the entire system acquisition process, from concept development through operational test and evaluation. The LHX MANPRINT research program described in this report focused on conducting MANPRINT analyses early in the system acquisition process. For this reason, steps six and seven of the SIMM were not relevant directly to the research team's effort. Furthermore, the research focus of the LHX MANPRINT effort tended to place a heavy emphasis on the analytic as opposed to operational or administrative aspects of the MANPRINT program. As a consequence, the research team concerned itself primarily with the development of analytic methods and their application to the LHX program. Direct support for the LHX MANPRINT program, such as preparation of system MANPRINT management plan, was not considered to be part of the LHX test-bed research program. The analytic nature of the individual projects resulted in a focus by the research team on step 5, MANPRINT supportability analyses.

The environment of the LHX system acquisition program itself provided an excellent test of the generality of the SIMM in its ability to serve as a conceptual framework for guiding MANPRINT analyses. The LHX was in early stages of concept development at the beginning of the research effort. Doctrinal concepts on how the LHX would be employed, mission profiles for the LHX, and the technologies which would be incorporated into the system were all under investigation or in early stages of development.

While the LHX acquisition process had not proceeded to a level adequate to support application of the SIMM in its entirety, the general principles underlying the SIMM were important influences in shaping the approach taken in the LHX projects described in this report. Efforts expended were conducted with an orientation that they would be building blocks for a full MANPRINT effort by future scientists. Perhaps the most important principle of the reported activities is that of

examining a materiel system as only one subsystem contributing to the performance of Army units. The approach was to focus on total system performance, not the performance of the materiel system in isolation. Figure 3 illustrates this principle. At the top of the triangle illustrated in Figure 3 is system performance. Within this context, a system is defined as an organization using the materiel system under investigation. At the center of the triangle is the materiel system of interest. At the two ends of the base of the triangle are system operability and system supportability factors.

As noted above, the focus of the LHX MANPRINT research program was on MPT supportability and affordability. Consistent with the SIMM, the research approach focused on the investigation of MPT factors within the context of system performance. All of the methods developed in this effort were constructed to provide information concerning MPT factors as they influence the performance of the organizations using the LHX or the life-cycle cost of the LHX program. The research team also made a concerted effort to acquire information as part of a method development process, applicable across efforts, not just for the LHX acquisition process.

One of the advantages of the SIMM is that it provides a general structure or approach for thinking about MANPRINT. An excellent example of this will be seen in the discussion of the LHX MANPRINT Integration research effort. This project focused on the organization and analysis of MANPRINT information for an ASARC decision briefing. While the briefing would take place before a design for the LHX was available, the design verification step in the SIMM served as an excellent model for the research effort. In the case of the LHX MANPRINT Integration effort, the research team was organizing MANPRINT input for a concept verification rather than a design verification.

The general approach taken by the LHX research team during the entire research program is best illustrated by Figure 4. The team attempted to examine the relationships among three sets of emerging factors: doctrine, design, and MPT. All of these factors were in a state of flux throughout the LHX MANPRINT research program. For example, doctrinal factors which had to be considered in LHX analyses included the mission profiles to be flown by the LHX and the structure (2 versus 3 level) of the maintenance organizations and process supporting the aircraft. Because no contractor design for the LHX was available, the research team used the reliability, maintainability and availability (RAM) goals articulated in the LHX RAM Rationale Report (U.S. Army Aviation Center [USAAVNC], 1985c) to represent the materiel system. The MPT factors considered in the LHX research program were focused primarily on system maintainers and support personnel because the LHX design was predicated on a single operator at the beginning of the research effort. As the research effort was ending, this "given" was also changed.

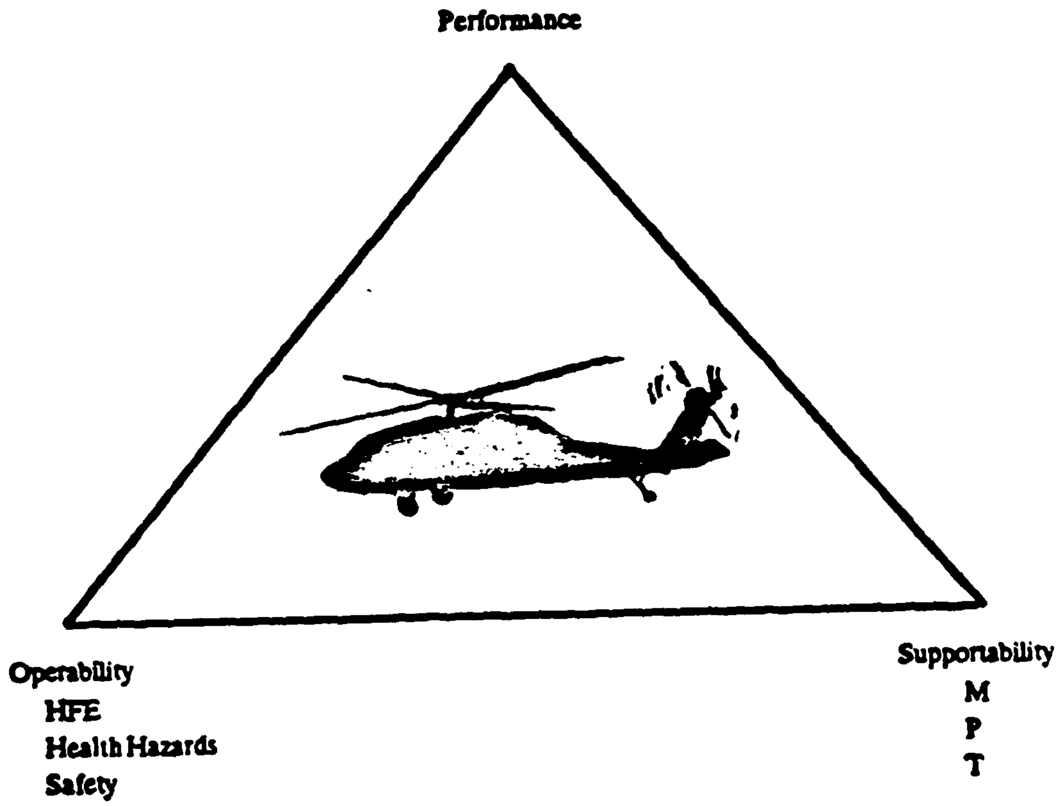


Figure 3. Total system performance.

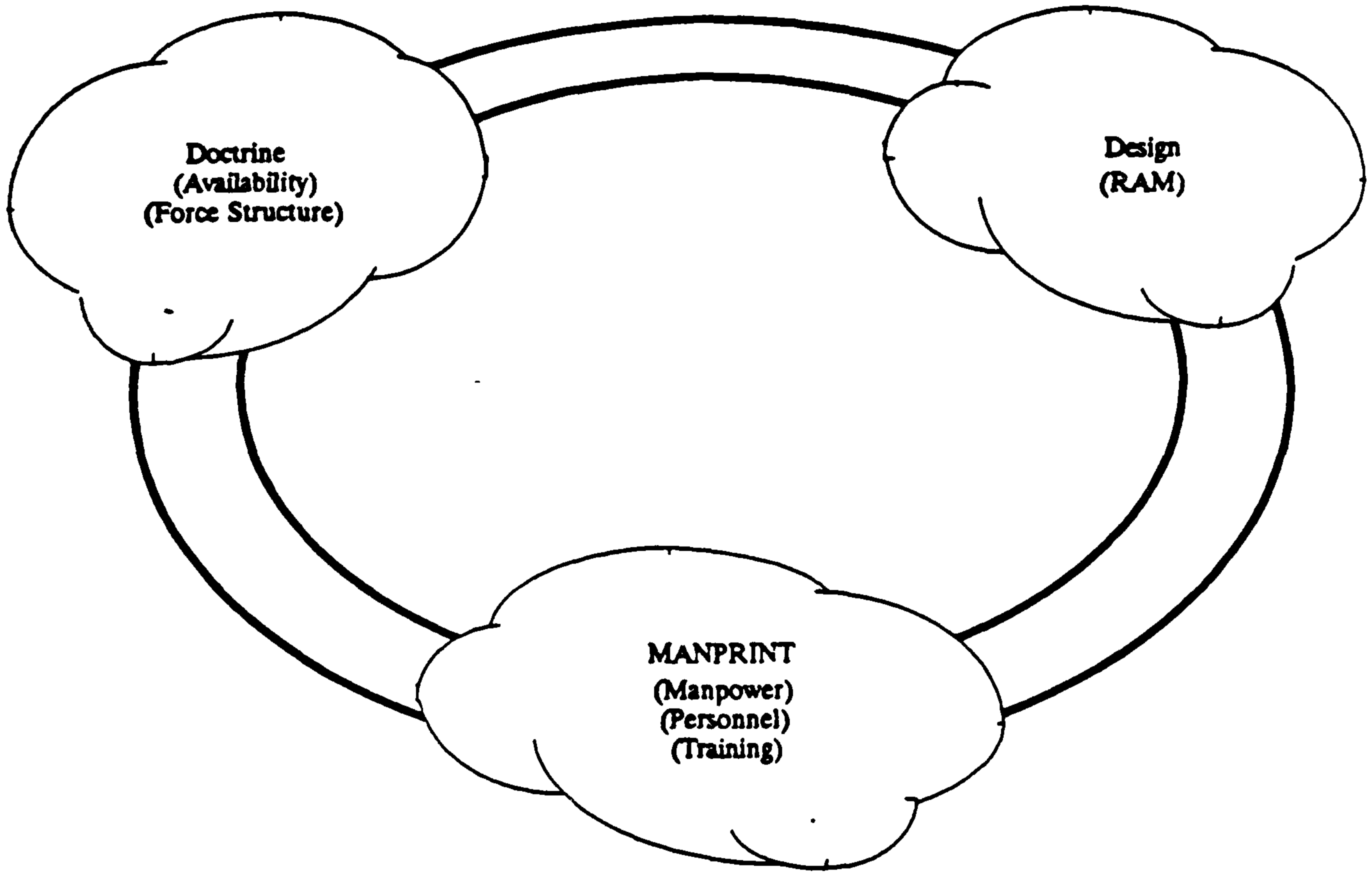


Figure 4. General approach.

The evolving nature of doctrinal and design data in the LHX program was considered to be typical of the environment which would be found early in the system acquisition process for any major materiel system. As noted above this was a major factor influencing the research and method development approach of the LHX MANPRINT research team. The current authors believe that the major challenge facing MANPRINT researchers early in the concept exploration phase of the weapon acquisition process is to provide methods that allow system designers to evaluate easily and rapidly the MPT implications of changes in emerging doctrine and design concepts. This requirement will change for systems procured through a nondevelopment item (NDI) procurement process. In NDI procurements, very detailed system design and system performance data should be available at the earliest stages of the procurement cycle.

At the concept exploration phase of a typical weapon system procurement cycle, methods that provide a single point estimate of manpower, personnel or training requirements are not the best tools to use. The standard error of estimate associated with a point estimate at this stage is potentially quite large. The problem becomes one of "fixing" a point estimate that is viewed as "real" too early when in fact, the actual point estimate is quite different than the one that can be determined with more validity later on. In fact, the lack of reliable data regarding technologies and design specifications make the determination of point estimates at the concept exploration phase an impractical goal. At the concept exploration phase, the methods should provide the system developers with a means of assessing the range within which MPT factors would fall with changes in macro-level design and doctrinal parameters.

As the system design concepts are more fully developed and the data become more reliable, methods capable of providing more accurate estimates of the individual operator and maintainer MPT implications on requirements of the system design become more appropriate. Figure 5 illustrates this principle. With the passage of time and development of more reliable design data, the range of the MPT estimates should narrow.

The primary value of early-on MPT estimation methods is to prevent system designers from making decisions early in the design process that would place the MPT demands outside of an acceptable range at the time the system is fielded. The range of acceptability is primarily a policy decision to be made by the Army. The development of methods that would allow determination of the impact of such design and doctrinal factors on the MPT factors was the focus of this research effort.

In summary, the conceptual framework for the LHX research program was based on the SIMM described in HTI's MANPRINT approach. When the attempt was made to apply this conceptual framework to the LHX, several principles emerged as particularly relevant. These principles included:

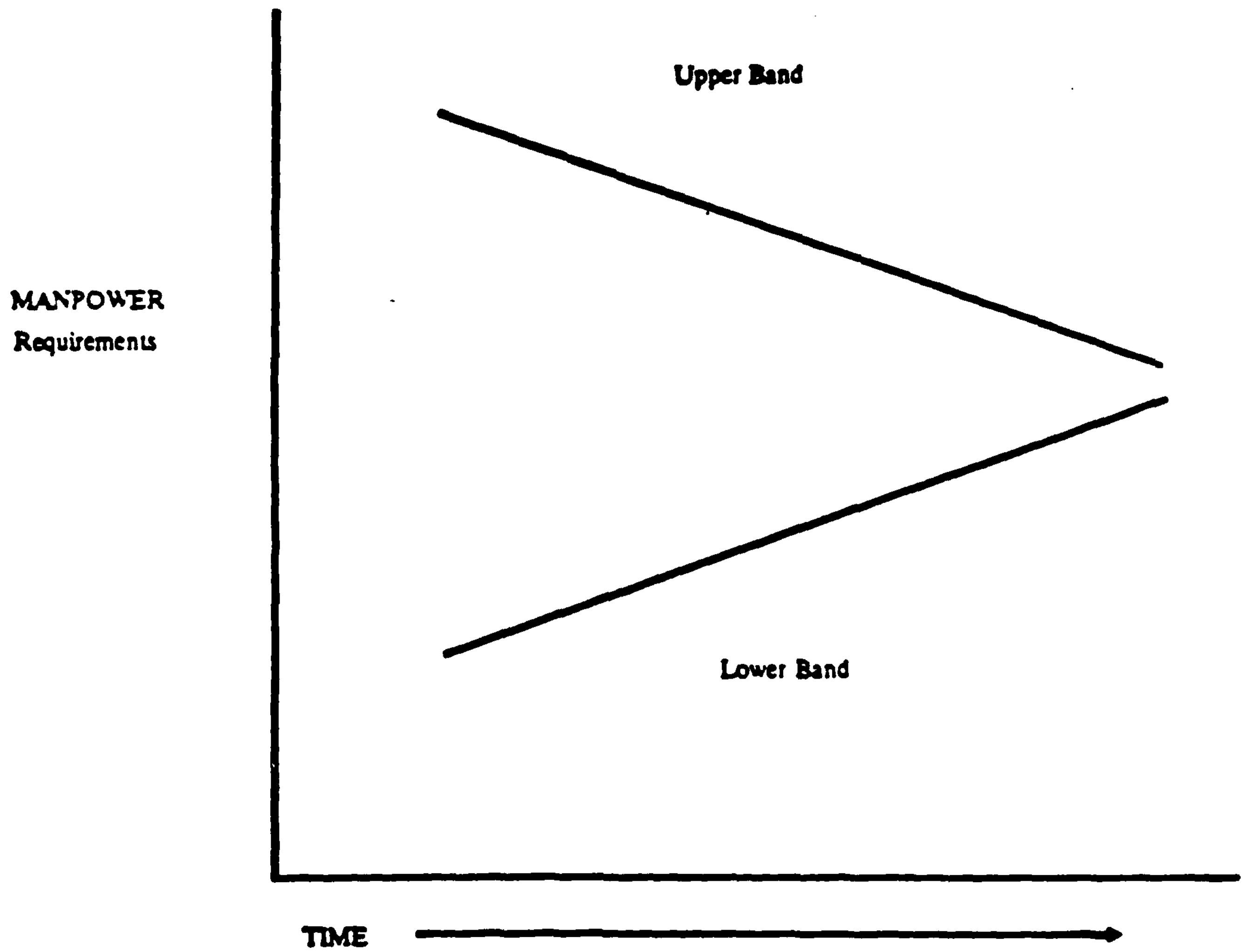


Figure 5. MPT estimates over time.

1. The use of a total systems approach which would capture analytically the concept of the Army fielding units rather than materiel systems.

2. The need for methods with a primary objective of preventing premature design decisions that would result in unacceptable MPT implications.

3. The need for a top-down approach that would allow rapid evaluation of MPT factors based on changing doctrinal and design characteristics. This top-down approach can be distinguished from a bottom-up human factors engineering approach which requires fairly detailed information on specifications of the components of the materiel system.

With the three principles outlined above as underlying conceptual biases, the research team began work on the development of a set of applicable MANPRINT methods. The next section of the report provides an overview and road map to the series of research projects conducted as part of this programmatic effort.

The LHX Organizational Modeling Research Program

Introduction

Perhaps the most significant methodological developments and analyses conducted in the LHX MANPRINT research program were in the area of organizational modeling. The LHX organizational modeling research effort consisted of three distinct phases. In the first phase, researchers developed and evaluated a prototype method for examining maintenance manpower requirements for an LHX-pure organization. The primary purpose was to demonstrate the feasibility and utility of such a method. The second phase was focused on the development of a more sophisticated method for examining the maintenance and supply manpower requirements to support a combat aviation brigade (CAB) equipped with the LHX. The automated model developed has been labeled the MANCAP model. The third phase in the organizational modeling effort converted the Apple computer run model developed in the second phase to an MS-DOS environment and modified the model to increase its flexibility for application to predecessor systems.

Goals

In 1985, ARI was asked by the LHX PM's Office to interpret LHX RAM data for MANPRINT implications. In keeping with the Vice Chief of Staff's guidance that the Army's goal is field units as opposed to weapon systems, the research team established a design concept for construction of a model treating the weapon system (LHX) analytically as a combat organization performing its mission.

The primary goals for the organizational modeling effort were two-fold. The first goal was to develop a method which would allow estimation of operator, maintenance and support manpower requirements along with system mission capability early in the concept development phase of the system acquisition process. The second goal was to provide analytic support to the LHX PM and calculate expected mission capability and manpower savings for operator, maintenance and support personnel based on LHX RAM data. These two general goals were relevant for all three phases of the organizational modeling project. Specific objectives for each of the three phases are described below.

Phase I: Development and Demonstration of a Prototype Organizational Modeling Method

Overview

When the first phase of the organizational modeling effort was initiated, the research team began the project with a preliminary conceptual framework to guide their work. As the research progressed, the SIMM conceptual framework and prototype model evolved interactively. The relevance of the conceptual framework and design of the method to the needs of the systems acquisition community were ensured by the demands on the research team to provide analytic support to the LHX PM. The paragraphs below describe the objectives, approach, and method developed in the first phase of the organizational modeling research effort.

Research Objectives. The primary objective of Phase I of the organizational modeling effort was to develop a portion of the analytical methods required to assess and plan for MANPRINT supportability of a major weapon system. Specifically, the research was intended to develop the necessary method and models to determine the inter-relationships and cross impacts of four sets of factors. The factors to be included in the model developed in Phase I were:

1. Materiel RAM data;

2. ILS planning factors;

3. Mission capability; and

4. MPT requirements.

The second objective of the effort was to demonstrate the feasibility of the method by assessing the impact of the LHX RAM/ILS factors on manpower in a representative mission scenario. The methodological demonstration was expected to produce results that would have immediate and significant use to the LHX acquisition planning community.

Research Approach. The approach to Phase I of the Organizational Modeling research effort involved five basic steps. The five steps included:

1. Conducting a front-end analysis process;

2. Determining the desired characteristics of the method;

3. Developing a prototype model for a method demonstration;

4. Applying the prototype model to the LHX; and

5. Revise the prototype model based on lessons learned in the application to the LHX.

As the research effort evolved, steps four and five were iterated as new information and data became available to the research team.

The Front-End Analysis. The SIMM suggests that the first step in the MANPRINT process is to implement a FEA process on the target system and relevant predecessor systems, utilizing available FEA techniques to collect information, performance data, performance requirements, etc. As a part of this process, research was conducted to establish the context in which the method would operate and to develop the framework for subsequent data collection. Since the LHX was serving as a test bed for the development of this portion of the MANPRINT method, the acquisition process as it was being implemented for the LHX was the focus of the research.

The starting point for the HTI FEA process was an examination of the LHX acquisition strategy to identify the major milestones anticipated and the timing of information requirements as well as data availability and sources. Once familiarity was gained with the LHX timetable, efforts were concentrated on obtaining as much information as possible on the LHX in terms of its design, employment, and support. That effort resulted in the following:

1. Descriptive information pertaining to the hardware, technologies to be used, employment philosophy and concepts, support philosophy and concepts, weapon system goals and constraints, and the target audience;

2. Development of a list of issues and questions pertaining to the LHX;

3. Identification of methods used to analyze the various aspects of the LHX during development; and

4. Identification of organizations and activities responsible for various aspects of the acquisition.

Once an adequate description of the LHX was established, the focus of the research effort was turned to the environment in which it would operate. This phase involved identification of:

1. Doctrine and regulatory guidance pertaining to Army aviation operations;

2. Existing force structure and missions;

3. Personnel descriptions and the personnel management system in general; and

4. Unit, individual, and collective training policy and procedures.

The results of the research were a description of the LHX and its anticipated support systems, a description of the environment in which development would take place and a description of the environment in which the system would operate. In addition, the effort identified issues and questions surrounding the LHX concept. The results of the FEA served as the context for the modeling effort.

Desirable Characteristics of the Method. The findings from the above discussed analysis indicated that the LHX program involved a great deal more than designing a new aircraft. The hardware to be incorporated in the LHX included a number of technologies which were barely out of the concept development phase. The LHX program was also identified as:

1. Pioneering a major change and streamlining of the acquisition process;

2. Anticipated to alter markedly the MOS structure within the Army Aviation Branch;

3. Investigating methods to change the equipment training development process completely;

4. Serving as the vehicle to investigate a major change in maintenance doctrine; and

5. Being introduced into the recently organized Army of Excellence (AOE) force structure.

Furthermore, the LHX program was the first major acquisition project for the recently organized Army Aviation Branch and the first Army weapon system to implement the emerging MANPRINT doctrine at the earliest stages of development.

In short, at the start of the organizational modeling method project, the LHX was a hypothetical system being introduced into an uncertain environment using new methods and procedures. As a result, the availability, applicability, and

accuracy of LHX data were expected to change and continue to change rapidly. It was also likely that the goals and objectives of the LHX program, particularly the RAM/ILS objectives, would change as the acquisition process for the LHX matured. These characteristics of the acquisition process suggested three requirements for the organizational modeling method:

1. A broad top-down approach. There was a need to assess MPT feasibility without the data that would have allowed for precise MPT estimates;

2. An ability to conduct rapid sensitivity and "what if" assessments, and

3. The avoidance of point estimates. Even the best point estimates are likely to be wrong, given sufficient time. Accordingly, the value of a point estimate effort declines rapidly with time. In contrast, an assessment of a spectrum or continuum of feasibilities can still be valuable as an early estimation and is not only amenable to change, but recognizes the expectation of change.

Based on the requirements listed above and the results of the FEA, the research team identified a set of model characteristics considered critical for successful development of an organizational modeling method. The researchers concluded that the organizational modeling method was to serve as an analytical tool used in assessing the impact of system design and management alternatives on manpower requirements. The model would be developed to aid in the selection, generation, or elimination of alternatives starting in the concept exploration phase and continuing throughout the acquisition cycle. To meet this goal, the method needed to be flexible, relatively fast, and require a minimum of computer expertise to operate.

Flexibility, speed, and simplicity were considered essential characteristics for several reasons, all of which are derived from the objectives of early MPT assessment. First, flexibility is required to remain synchronized with the acquisition process. It is characteristic of materiel acquisition to start with a set of broad design and employment concepts and a set of general resource constraints. The design and employment concepts are systematically refined which, in turn, more closely defines the resource requirements and allocations. The organizational modeling method had to be capable of adapting to the changes not only in data but in the target environment. Furthermore, it had to be capable of operating in both a deductive and inductive mode. That is, it had to be capable of quantifying the impact of alternatives as they were presented as well as generating a range of feasible alternatives within a given set of resource constraints. Moreover, it had to be able to operate with incomplete or uncertain data and, as the weapon system matures, incorporate new data quickly.

The goals of flexibility, speed, and simplicity enable widespread use of the method. Particularly during the early stages of the acquisition process, the range of alternatives is extremely broad and organizational affiliations and backgrounds of the personnel examining them vary widely. It was intended that, once fully developed, the method would be available to a wide range of analysts and would be used to compare and select an entire spectrum of manpower alternatives. To achieve that end, the method had to be responsive in terms of time and could not require a special group of personnel or equipment to operate.

Development of the Prototype Model. After establishing the desirable characteristics of the organizational modeling method, the research team then focused on the development of the method itself. Since Phase I of the organizational modeling effort was primarily a demonstration of the feasibility of developing an organizational modeling method, the decision was made to focus on a target organization that was familiar to members of the LHX community. By using this type of an organization, it would be relatively easy to determine whether the output provided by the model was realistic and in an acceptable format for use by members of the systems acquisition community. The Attack Helicopter Company (AHC) was chosen as the target organization because its employment doctrine and mission package are representative of the widest spectrum of LHX units. Further, the unit itself provides a level of complexity which allows for an unambiguous demonstration of the feasibility of applying the new method.

A general structure for the prototype method was developed, which incorporated seven major steps. Each of these steps is described briefly below. Following the description of the seven steps, a more detailed description of the structure and application of the actual model developed in Phase I of the effort is provided.

Step 1 - Identify Model Factors to be Established and Held Constant. The first step in the organizational modeling method is the identification of system design, MPT, or mission requirement factors which will be held constant in subsequent analyses. The role of the constant factors may be likened to effectiveness factors in a Cost and Operational Effectiveness Analysis (COEA). In the COEA, effectiveness is held constant and resources are varied to identify viable alternatives. For the prototype organizational modeling method, pertinent RAM/ILS factors and an appropriate set of mission factors were identified as the effectiveness measures. This first step was particularly important during the development of the prototype method because the factors identified as constants became structural elements programmed into automated portions of the method.

Step 2 - Identify and Define Target Unit. In this step of the method, the user initiates a system definition process to link materiel system performance to organizational performance.

The materiel and organizational system is treated as a combination of personnel and materiel working together to accomplish a mission. An analytic modeling process which works toward an optimized presence of people and materiel, enabling required mission performance, was used to define and represent the materiel and organizational system.

Step 3 - Define the Support Target Unit. This step identifies and allocates the appropriate share of combat service support (CSS) to the target organization. Included are those CSS resources and services provided in the tactical force structure which (1) are needed to sustain the effectiveness of the unit and its equipment when it is employed to perform the previously identified combat mission and (2) are affected by the introduction of the new weapon system.

Step 4 - Develop a Reference or Predecessor Set of Data Inputs. Two sets of reference data which represent the target organization before and after introduction of the new weapon system are developed. Later in the process, the manpower impacts are inferred from the comparison of the two sets of data. Ideally, the reference data sets should be very precise descriptions of the unit. As a practical matter however, the dynamic nature of the Army force structure and doctrine require an arbitrary freeze of the "before" reference data at an agreed upon point in time and the "after" reference data must be based upon the best information available pertaining to the new system. As was previously mentioned, in many cases data on the new system are predicated on a set of assumptions. Although the analyst is striving for the highest level of accuracy possible, identification of the relevant factors is the critical element of this step. So long as a complete set of factors is developed, the nature of the model ensures that the data itself can be updated as new information becomes available.

There was some concern among the interested Army participants that developing the needed reference inputs amounted to de facto unit design. This effort confined itself to development of a MANPRINT capabilities model and did not undertake the comprehensive examination needed for development of a strawman unit design. However, based on the research objective of the this effort and the capability of the method, the research team did attempt to infer a required personnel organization for combat for the target organization.

Step 5 - Select Factors to be Varied. The factors selected during this step are varied systematically by the model in order to find the mix that makes optimum demands on the resources available to the target organization. The basis for selection of these variable factors are: (1) expected importance of the factor to the major functional area of interest, (2) magnitude of the potential value range of the factor, (3) the range of possible applications of the factor within the organization, and (4) known constraints on the factor.

Step 6 - Identify Factors to be Tested. Step 6 of the method involves the identification of factors that are expected to have an impact on manpower supportability but do not lend themselves to automatic variation by the model. Unlike the factors in Step 5, these factors will be input changes to the reference data identified in Step 4. This step in the method is one of the primary interfaces between the analyst and the automated portions of the method. The analyst's modifications of input factors change the parameters within which the systematic variations of Step 5 are made.

Step 7 - Run the Model. Once Steps 1 through 6 have been completed, the final step is for the analyst to run the automated sequences of the model and to analyze the outputs to determine MPT impacts, identify critical factors and the sensitivities of the critical factors to variations in the reference data. The following are some of the products that result from the application of the method just described:

- Projected change in manpower requirements from an assumed reference point;
- Sensitivities and uncertainties relating to key factors which may suggest additional model excursions;
- A statement about manpower feasibility for the system of interest;
- Trade-off algorithms, derived or estimated;
- Graphic and tabular portrayal of trade-off algorithms; and,
- Documentation and briefing of assumptions, findings, and observations.

The organizational modeling method described above was designed to be only partially automated. The method is highly interactive with certain steps requiring manual actions and decisions made by the analyst. The method was designed for use by an analyst familiar with the system under investigation. The method was designed as a computer-aided manpower alternative generation and evaluation process. The method and computer models provide a structure for examining manpower issues in the concept exploration phase of a major system acquisition program. The next section describes the structure of the automated portions of the prototype organizational modeling method developed in Phase I of the effort.

Model Structure

A simulation approach was chosen for the basic structure of the automated portions of the method with iterative refinement used to gain analytic fidelity. The overall computer model

simulates the ability of the organization to perform its mission prrfile. This modeling process requires the user to incorporate a materiel and organizational system mission performance measure. Combinations of manpower alternatives realizing a consistent level of mission capability performance were considered equally effective in the model.

The modeling process requires four model components to define mission capability demands on manpower. The model components are illustrated in Figure 6. Each of the four modules is described briefly below. Since this prototype version of the model has been superceded by the MANCAP model, details of the quantitative functioning of the model are not discussed.

Mission Availability Module. The mission availability module simulates the effect of the mission profile on aircraft availability from a reliability failure perspective. A model of the mission cycle has been joined to the wartime 2LM administrative and logistics delay time (ALDT) model published in the LHX RAM Rationale Report (USAAVNC, 1985c).

Figure 7 is a summary representation of the model flow. The mission availability module is loaded with the number of aircraft in the organization and the mission requirements. The processor selects aircraft to fly according to time-phased mission requirements. It sends aircraft to maintenance based on hours flown and the mean time between essential maintenance actions (MTBEMA). Aircraft are routed through the maintenance structure and returned to a mission ready status according to the probabilities and delay times in the ALDT model.

Model output includes the aircraft sent on each mission, the number of times that float aircraft were issued, and a summary of mission and repair data. In turn, this generates a basis for operational, maintenance and supply work loads. These become the required organization for mission capability performance and are used as inputs to the next module.

Two versions of this module were developed. The first and primary version is a Monte Carlo simulation of the events of the mission and repair cycle. The second is a spreadsheet based on expected value equations. The simulation provides substantially more detail than the spreadsheet in terms of the when and how many times during the scenario a particular event occurred. However, to obtain valid information, many repetitions (in this case more than 30) must be run for every excursion. Therefore, compared to the spreadsheet it is slow--approximately 2.5 hours versus seconds for the spreadsheet. The simulation is the primary tool used to conduct detailed analyses, and the spreadsheet is the preferred tool when performing "what if exercises."

Organization for Combat Simulation Module. Results of the mission availability module simulation establish aircraft

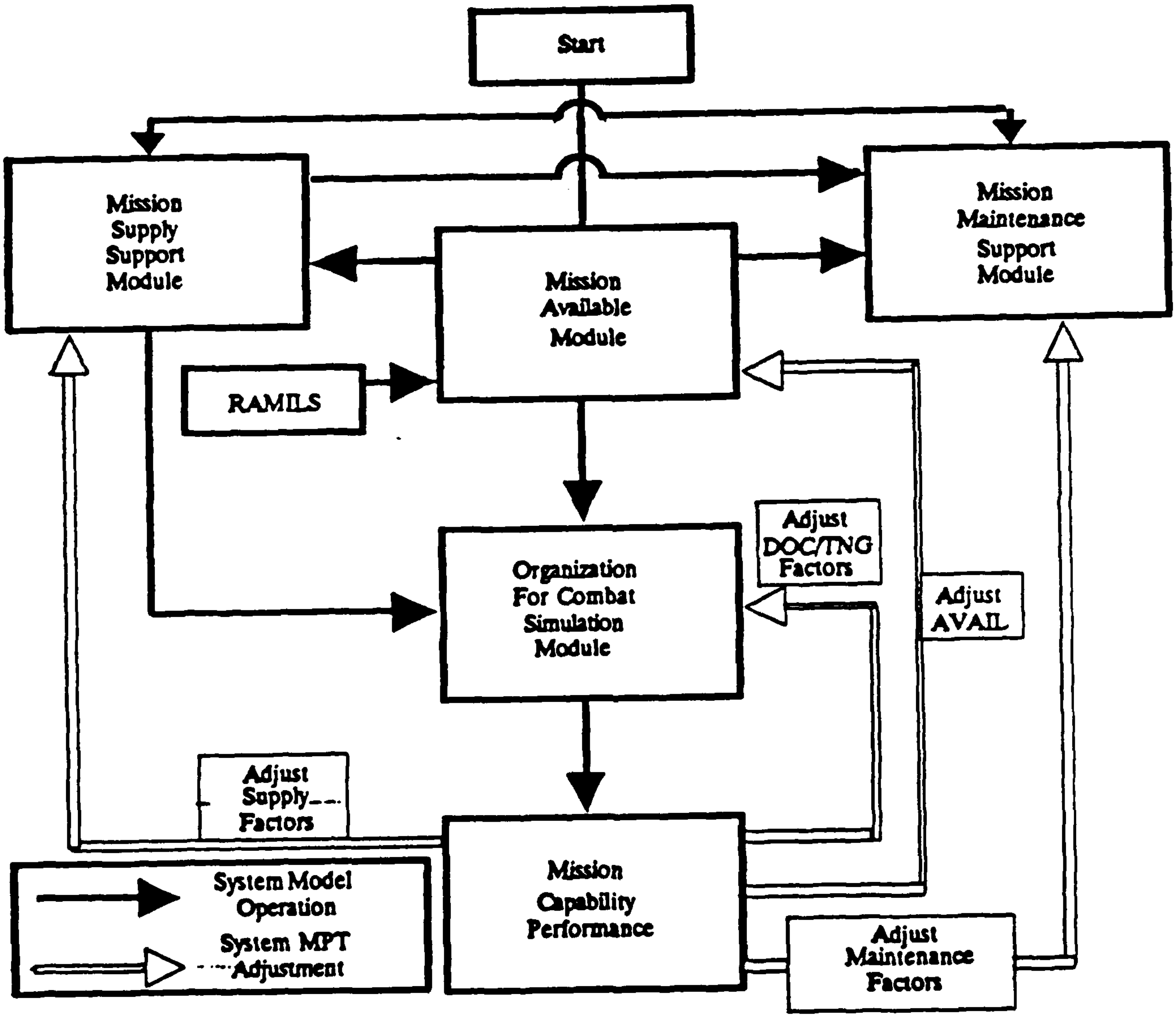


Figure 6. Manpower and mission capability model (Phase I).

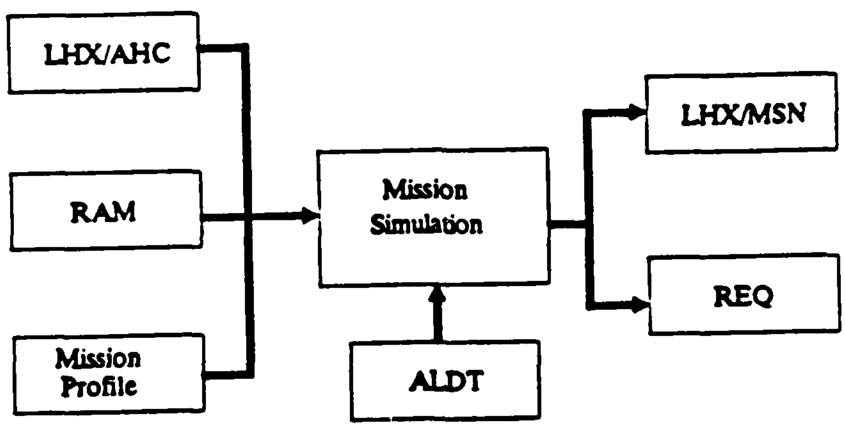


Figure 7. Mission availability module.

availability and manning requirements for operators, maintainers and support personnel. The organization for combat simulation module combines the availability of personnel and aircraft and compares them with the requirements of the objective mission capability. In this module, degradation resulting from combat losses as well as allowable personnel transfers are included in the simulation.

Figure 8 illustrates the organization for the combat simulation module. The inputs required for this module include a transferability table, degradation probabilities, and damage probabilities developed by the analyst as well as the outputs of the combat simulation module. The preprocessor allows the analyst to build and store alternative sets of inputs for later analysis. These sets of inputs or alternatives are referred to as unit data files. When called upon by the organizational capability simulator, the inputs stored in the unit data file are loaded electronically. The unit capability simulator transforms this data into unit capability distributions, expected assignment frequencies, expected assignment penalties, and line item needs and surpluses. During the processing stage, the simulator can develop and save a set of survivors for each replication by sampling the initial strength using the degradation probabilities or the user can call a previously developed survivor file. At any time following the simulation, the user may print out the capability distribution, assignment frequencies, assignment penalties and line item needs and surpluses. Each replication is saved automatically to the capability replication file.

Mission Maintenance Support Module. This module is a spreadsheet which calculates maintenance requirements based on work loads identified in the foregoing two simulations. Figure 9 illustrates this module. The work loads are apportioned to the maintenance levels based on the maintenance concept for the weapon system. Once apportioned, the workloads can be converted to manpower using standard manning factors such as the manpower requirements criteria (MARC). In the event a standard manning factor is not available, the work load may be calibrated to real or reference organizations. The products of this module are the maintenance personnel required and the maintenance man-hours (MMH) available per operating hour.

Mission Supply Support Module. This module is an additional model component that is applicable at battalion level. It determines supply manning as a result of the supply requirements of the AHC operating LHX at mission area analysis (MAA) flying hour levels. MARC factors may be used if available or, alternatively, supply support factors may result from calibration to real or reference units.

The four modules, when run sequentially, become the MANPRINT capabilities model. Although each module can be run independently, maximum utility is gained by using the outputs of one module as the input to the next.

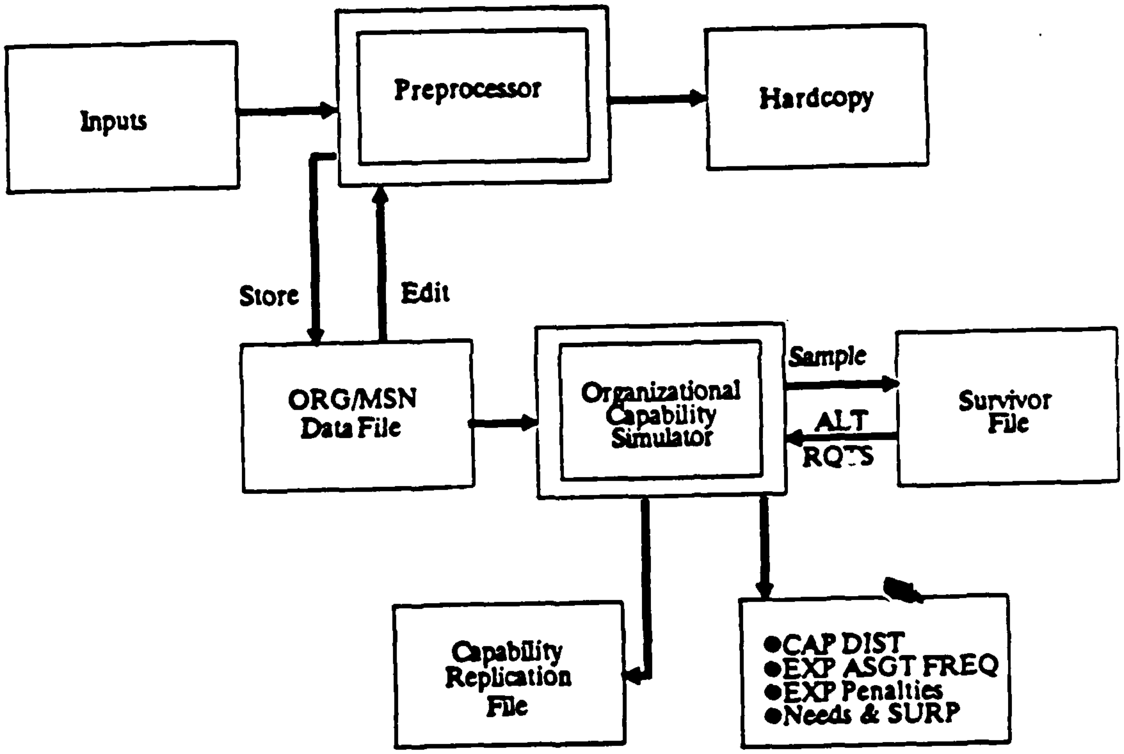
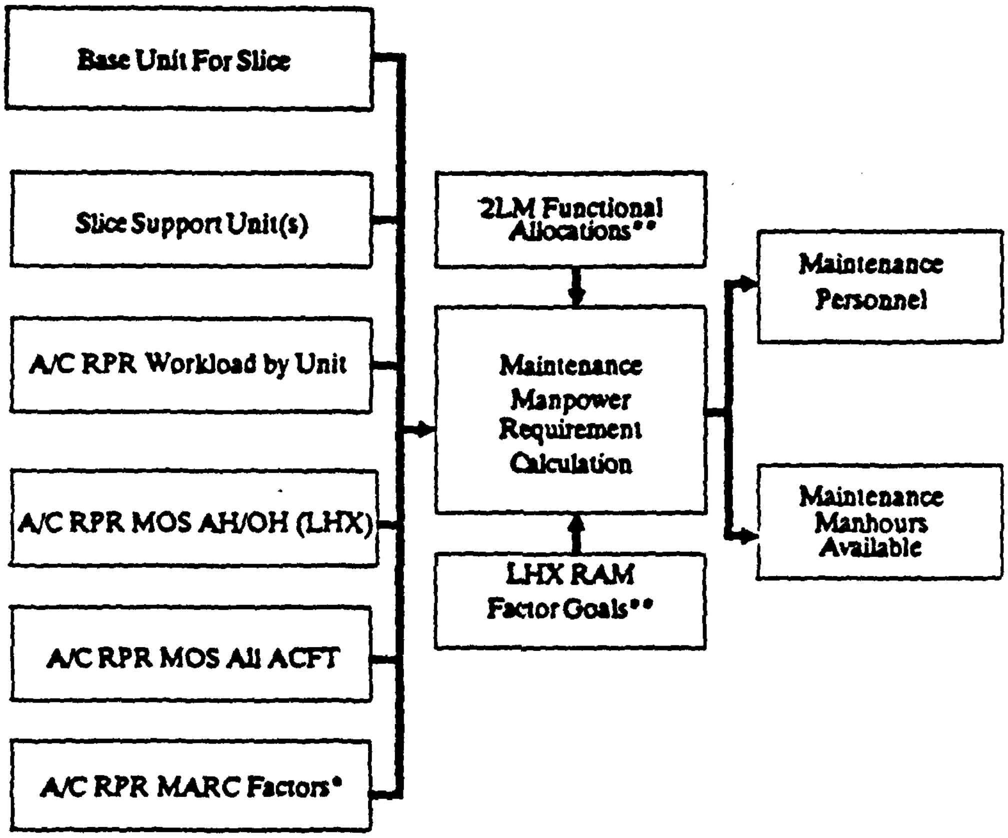


Figure 8. Organization for combat simulation module.



*Initial application allocated in proportion to aircraft population (Manpower Analysis, RAM Rationale Report).

**Not required if LHX 2LM MARC factors are used.

Figure 9. Maintenance support module.

There are three general sets of data that reside within the model. The automated model will generate any one of the three sets of data as a "what if" data set given the other two data sets as input provided by the analyst. The data sets are performance characteristics, mission capability, and resources required. Listed below are the data elements for mission capability and resources. Table 1 displays the elements associated with performance characteristics.

Mission Capability

1. Duration of scenario
2. Duration of mission
3. Mission cycle (engagement versus standby)
4. Equipment per mission
5. Environmental condition

Resources

1. Manpower
   a. Operators
   b. Support Personnel
2. Equipment
   a. Assigned Aircraft
   b. Float Aircraft

It is up to the analyst to select the two sets of factors to be held constant within each excursion. The third set of data will then be derived using the model. The analyst may then compare and analyze the outputs to establish the ranges of feasibility, sensitivities of data factors of interest to variations in other factors, and in some cases, suggest additional factors to be tested or additional excursions required to complete the investigation of a particular factor. For example, when the model is used in the resource requirements mode, systematically varied iterations are run to seek the minimum resources needed to achieve the mission capability.

Application of the Prototype Method to the LHX

Throughout the method development process, the research team was interacting with members from the LHX PM's office. Since the LHX acquisition was serving as the test bed for this research project, the prototype method was tailored to provide a demonstration considered of value to the members of the LHX community. The application of the prototype method to the LHX was not conducted as a single demonstration analysis after the development of the prototype method was completed. Instead, the method development and application for the LHX was undertaken as an ongoing and interactive process. Tentative results from trial runs of test versions of the automated modules were examined by members of the LHX community, and their comments were considered when revisions were made to certain portions of the modules such as the nature and format of output provided by the modules. The results of the LHX analyses were reported in an early research report (Robinson, Lindquist, March & Pence, 1988) and various briefings. The discussion of the application of the prototype method to the LHX, which is provided below, is focused on topics which further illustrate the method, not the results of the analyses.

Table 1

Performance Characteristics

1. Rate of assignment of operators

2. Rate of direct maintenance man-hours per calendar period

3. Rate of productive maintenance man-hours per calendar period

4. Mean time between essential maintenance actions

5. Mean time to repair (MTTR)

6. RAM probabilities and delay times for:

   a. Repairs performed at the AHC:

      (1) without parts

      (2) with parts from the Headquarters and Supply Company (HSC) prescribed load list

      (3) with parts from the Division authorized stockage list

      (4) with parts located by an in theater lateral search

      (5) with parts from CONUS

   b. Repairs performed at the HSC:

      (1) without parts

      (2) with parts from the HSC prescribed load list (PLL)

      (3) with parts from the Division authorized stockage list (ASL)

      (4) with parts located by an in theater lateral search

      (5) with parts from CONUS

7. Personnel transferability

8. Maintenance support available

9. Float:

   a. Criteria for issue

   b. Delay time for issue

Assumptions and Parameters. As was discussed earlier, a major problem in the application of MANPRINT estimation methods at the very early stages of a system acquisition program is the small amount of definitive data available on system design. The stage of development of the LHX required the use of a number of assumptions for the application of the prototype method (sample assumptions are listed below). It is important, however, to remember that although the list of assumptions is fairly lengthy, the model was designed specifically to facilitate updates as new information becomes available or as elements are changed.

1. It was assumed that the following constraints and goals would be achieved:

   (a) The LHX would achieve single-pilot operability;
   (b) The LHX would be maintained using a 2LM system;
   (c) The LHX-PMO ILS/RAM factor goals could be used to predict system capabilities; and
   (d) The BIT/BITE planned for fault detection and isolation could achieve reliability objectives.

2. The key elements of the mission selected were:

   (a) Continuous operations.
   (b) Eighteen hour cycles consisting of two consecutive missions of 3-hour durations each and a 12-hour stand down after the second mission.

3. Aircraft Requirements

   (a) For comparability with current unit holdings and with other LHX studies, the number of LHX organic to an AHC was continued at 11.
   (b) Float LHX were assumed to be provided to sustain unit operations when unit aircraft were not mission capable supply.

4. Officer/Warrant Officer Pilot Requirements

   (a) 50% of flight operations were assumed to be conducted at night.
   (b) AR 95-1 crew endurance guidelines were followed.
   (c) For resiliency, the unit must be fully mission capable at 90% pilot strength.

5. Enlisted Requirements

   (a) As observed in the current AOE Table of Organization and Equipment (TOE), one repairer was required at AHC level per aircraft.
   (b) Similarly, the first sergeant, two platoon sergeants and headquarters section driver/radio telephone operator were continued for technical supervision and continuity of operations.

6. Personnel transferability to sustain unit capability under degradation was prioritized. In the absence of scenario specifics, all skill positions were accorded the same probability of degradation.

7. The AHC was considered to be composed of a headquarters section and two identical LHX platoons.

8. The probabilities of LHX repair requirements and ALDT as published in the LHX RAM Rationale Report (USAAVNC, 1985c) were assumed to be correct.

9. The LHX Operational and Organizational (O&O) Plan (USAAVNC, 1985b) functional description of 2LM--user and depot--for LHX was used in conjunction with the Field Manual (FM) 1-500 functional allocations for three-level maintenance (3LM) to project a functional allocation for LHX 2LM through user level. In the absence of a non-divisional aviation intermediate maintenance (AVIM) unit under 2LM, the Aviation Maintenance Company (AMC) was assumed to be responsible for holding and maintaining float aircraft at division level.

The development of the above assumptions was, in reality, done as the need presented itself throughout each step of the method development effort. It is impossible to predict exactly what data will be available for a given materiel system or when it will become available in the system acquisition process. Researchers applying MANPRINT estimation methods early in the system acquisition process must be prepared to operate in and, must have tools applicable for this type of an environment.

Once the assumptions were in place, the next step was to identify the factors to be held constant within each excursion. Since the objective of the performance demonstration was to assess the impact of RAM/ILS factors on manpower, the RAM/ILS factors had to be held constant and the manpower factors had to be permitted to vary. Allowing manpower to vary demanded that the mission capability also be held constant. Therefore, constant factors were as follows:

1. RAM/ILS:

   (a) The rates of occurrence for failures,
   (b) The probabilities for the level that would provide repair parts,
   (c) Repair times,
   (d) Administrative delay times,
   (e) The characteristics of the 2LM concept,
   (f) Productivity of maintenance personnel, and
   (g) Rate of allocation of support maintenance personnel to assigned aircraft.

2. Mission:

(a) Cycle length,
(b) Duration,
(c) Aircraft launched per mission,
(d) Flight condition as pertains to crew rest,
(e) Rates of degradation,
(f) Permissible personnel substitutions, and
(g) Priorities of personnel substitutions.

The AHC was selected as the unit of interest for the reasons previously discussed. The AOE TOE was adjusted for the LHX. That is, authorizations pertaining solely to predecessor aircraft were deleted. In addition, the policy decision of retaining one repairer per aircraft, a first sergeant, two platoon sergeants, and a driver/radio operator was followed. The number of aircraft assigned to each company was set at eleven.

Step 3, definition of the CSS share for a more mature system, would ordinarily be calculated from either engineering estimates of the rates of occurrence of the various types of failures pertaining to each repairer MOS or, if available, from the manpower authorization and requirements criteria. In the absence of both of those, the LHX maintenance support slice was defined as the share of the total maintenance support--aviation unit maintenance (AVUM) and AVIM--in an Air Assault Division (AAD) allocated to the predecessor aircraft in an AHC adjusted for the LHX. Adjustments included elimination of capabilities rendered superfluous by the LHX and allocation of maintenance functions in accordance with the 2LM concept as described in the LHX O&O Plan (USAAVNC, 1985b). The procedure used to allocate the maintenance support parallels that described in the LHX RAM Rationale Report (USAAVNC, 1985c).

The next step was to develop a reference set of data inputs based on the decisions and definitions occurring in the previous steps. The application of the prototype method required generation of a new set of reference data as opposed to use of existing predecessor data because there is not a representative predecessor unit. The LHX scout/attack (SCAT) concept necessitates substantial changes in the AHC organization and eliminates several operator, observer and repairer MOS. The introduction of technology and the 2LM concept cause substantial redistribution of the maintenance workload. For those reasons, data from an AHC equipped with OH-58 and AH-1 aircraft would not suffice for use in the analyses.

The factors that were varied within the model were the personnel and equipment assignments to each mission. As missions were flown and degradation was experienced, the model made personnel assignments within the criteria established (crew rest, transferability priorities, etc.) to optimize the resource demands. The equipment assignments were based on the aircraft availability criteria.

Four factors assumed to impact on mission capability were tested through modification of reference inputs. The four factors examined included:

- Aircraft per mission,
- Simulation period,
- Personnel substitution criteria, and
- Degradation rates

Once the products of the MANPRINT capabilities model were assembled it was possible for the analyst to assess the MPT supportability for LHX units. The general conclusions and supporting output from the model were provided to members of the LHX community in a series of briefings.

Evaluation of Phase I

On the surface, the two primary goals established for Phase I of the organizational modeling effort were achieved. A prototype method for examining manpower early in the system acquisition process was developed and the method was applied successfully to an analysis of the LHX Attack Helicopter Company to determine impact of operational environment on skilled manpower requirements. A closer examination of the Phase I of the effort reveals a number of limitations to the method and demonstration analyses.

The AMORE (Analysis of Military Organizational Effectiveness) method (Robinson, 1984) served as a framework for the organization for combat simulation module of the Phase I effort. Like the AMORE method, the organization for combat simulation module allows for the degradation of personnel when assessing the availability of personnel to achieve an objective mission capability. However, as the research progressed, the ability to include personnel degradation became less critical and thus was not included in Phases II and III of the organizational modeling project.

While the generic steps in the organizational modeling method could be applied to any system, the computer models developed for the prototype project were specific to the LHX. That is, additional programming is required to transform the prototype computer models before they can be applied to other systems. Furthermore, the computer models were very limited in scope and required modification before they could be applied to organizational levels above the battalion, even for aviation units equipped with the LHX.

The results of the analyses conducted in the demonstration application of the prototype model were relatively simplistic and could have been generated through other, more time consuming

methods. The results provided directly by the model were limited primarily to manpower data with some conclusions related to personnel or training being derived from the manpower results and analysts' knowledge regarding aviation logistics and maintenance and the LHX. A major factor contributing to these results was the decision to limit the analysis to the LHX Attack Helicopter Company. By restricting the analysis to this level, the number of MOS involved was very limited and the maintenance and supply structures directly involved were simplistic. While the results were considered realistic and acceptable in format to members of the LHX community, there was also an immediate request for more complex analyses of higher level organizations.

Although there were a number of limitations to the method and demonstration analyses, the method was viewed as having great potential primarily in its use to examine rapidly the impacts of changes in reference data sets or assumptions regarding a developing weapon system. The successful demonstration of the feasibility of developing an organizational modeling method combined with requests from the LHX PM for more refined and detailed outputs led to the second phase of the organizational modeling project.

Phase II: Development of the MANCAP Model

Introduction

In an attempt to address the shortcomings of the Phase I effort, Phase II of the organizational modeling effort was initiated. Specifically, the second organizational modeling effort expanded the organizational model developed in Phase I to accommodate a division-size organization and apply it to an analysis of the LHX operating within a division organization. The results of the LHX Phase II analyses were reported in an early report by Lindquist, Robinson and Statler (1989a) and various briefings.

Background. As discussed earlier, Phase I was limited to the investigation of one LHX pure unit in the AAD which, in its current state, could not be expanded to include the investigation of manpower impacts of the LHX in higher level organizations. Although the AHC was selected to facilitate the construction and verification of the model, it also limited the applicability of the results. Specifically, model outputs were limited to operator and repairer requirements to support one AHC operating in an organization that supports multiple-type aircraft. Both the LHX and the non-LHX aircraft of the organization place simultaneous demands on support resources and should therefore be considered in the estimation of resource requirements. Also, the demonstration analyses of Phase I evoked questions regarding the support requirements of the LHX in higher level organizations.

Research Objectives. The objective of Phase II of the organizational modeling effort was to extend the method

demonstrated in Phase I to develop a new computer model which could accommodate the Light Infantry Division (LID) that pertains to and is affected directly by the introduction of the LHX into the force structure. At this organizational level, the method would allow for the analysis of the interaction of several different units performing a variety of missions with different equipment placing simultaneous demands on a wider spectrum of the combat service support structure.

The second objective of Phase II was to apply the new model to the LHX. As such, the method developed in Phase II of the organizational modeling effort used computer-based models to estimate the mission capability of the LID's CAB equipped with LHX aircraft performing a specific set of missions over a sustained period. The following functions were included in the model: mission scenario; aircraft maintenance; repair parts supply; petroleum, oils, and lubricants supply; and ammunition supply.

The model developed in Phase II was designed to provide increased resolution of model outputs and to examine the impacts of multiple mission profiles on the support resources of a division-size organization.

<u>Research Overview</u>

Specific LHX manpower issues provided the framework to ensure the development of a method that was useful in estimating manpower requirements of a developing weapon system. As such, the development process was an interactive process between MANCAP method development and LHX MANCAP application. The desire for increased fidelity of model outputs required that the model be detailed and system specific. However, throughout the development of the LHX specific model, care was taken to ensure that the overall design would result in a generic tool that could be applied to other weapon systems.

The approach that resulted in the MANCAP method consisted of the following five major steps:

1. Define system to be modeled;

2. Identify system operating scenario;

3. Develop functional description of system;

4. Develop computer-based model; and

5. Apply model to the system.

Step 1 consisted of identifying and describing the major components of the system to be modeled. Step 2 consisted of selecting an operating scenario for the system organizations in which the weapon systems are assigned to perform a specific

mission profile during a specified time period. During the development of a functional description, the chains of events of system operation and associated resources were identified. The fourth and fifth steps were performed concurrently in order to develop a model that addressed specific manpower issues for the LHX as well as a generic method that could be applied to other weapon systems. The fourth step was the aggregation of possible events, associated resources, operating scenarios, and model assumptions into a computer-based model that simulated mission performance and maintenance activities and estimated support resources required to maintain a desired level of mission capability. The final step was the application of the model to the LHX as it is designed to operate in the LID. A more detailed description of the MANCAP model development is provided below.

<u>Step 1 - Define System to be Modeled</u>. During Step 1 of the development process, the essential elements of information for each of the systems components were identified. The essential system elements were those data elements drawn from manpower attributes of the weapon systems concepts that when aggregated, addressed the manpower requirements of the weapon system operating in a division organization. To address these requirements thoroughly, weapon system characteristics, operating organizations, support organizations, and their relationships were identified. The manpower system attributes identified were classified either as assumptions or rules depending on their variability within the system. Appendix A contains a description of the manpower system attributes included in this effort.

Assumptions were defined as model elements that were fixed. That is, assumptions were built into the model structure and could not be changed without major modifications to the model structure. The number of assumptions was limited in order to maintain the flexibility of the model and the top-down modeling approach. Limiting the number of assumptions also helped ensure the ability to incorporate additional information that becomes available as a weapon system progresses through the acquisition cycle. Furthermore, designation of assumptions was limited to those attributes that are basic functions of a generic system and thus would not detract from the application of the method to other weapon systems.

Rules were defined as modeling parameters that were specific to the system modeled but could be adapted to the different systems and could be changed without major modification to the model. Rules were further categorized as semi-fixed or interactive parameters. Semi-fixed parameters were parameters that could be changed relatively easily with some additional programming if additional weapon system characteristics become available. Interactive model parameters were those rules that were able to be modified without additional programming to the model. These parameters were based upon the design goals of the system and served primarily as model inputs.

Step 2 - Identify System Operating Scenario. The second step in the development process was the identification of an operating scenario for the weapon system modeled. During this step the number of weapon systems operating per mission, the mission duration, the number of missions per operating cycle, the cycle length, and the mission intervals were determined.

Step 3 - Develop Functional Description of System. During this step, the major components of the system were integrated into an overall system operating structure. Specifically, the relationships among the overall sequence of operations, possible events, and resources required for each event were determined. For example, the LHX mission sequence served as the primary path of operation. Maintenance and supply operating sequences associated with the mission sequence were also identified for each organization because the information desired for the LHX included the impact of maintenance and supply operations on LHX mission capability. However, different operating paths may be identified for different weapon systems. Key resources were also associated with the appropriate level of the operating structure during this step, including the number and types of personnel required, supply requirements, and other CSS required to operate, maintain, and support the weapon system. Resource constraints were also identified to ensure that system operability was not achieved at the expense of resources not actually available or that were allocated for other existing systems.

Step 4 - Develop Computer-based Model. The development of the model was a iterative process driven by the types of information required for the LHX, and the request for a flexible and generic method of analysis. To satisfy the requirements described above, the computer model was developed by decomposing the system operating structure to individual operating modules of the overall organization. Specifically, the MANCAP model is comprised of three separate and distinct modules, displayed in Figure 10, which consist of an operations and maintenance module, a supply support module, and an operator support module. Together, the three modules provide a top-down evaluation of manpower implications based on RAM values. They are computer-based and can be exercised as concurrent or stand-alone modules.

The operations and maintenance module simulates the interaction of mission accomplishment and maintenance support on the basis of RAM characteristics, the probabilities of repair, the associated repair and delay times, and the mission scenario. The simulation incorporates a sequence of performance events and maintenance events linked through a "tub file" which operates as a work order management system. Weapons systems progress through the mission performance sequence until a mission affecting failure (MAF) occurs which is determined through the sampling of probability distributions. The maintenance performance sequence is then initiated which simulates the repair of the weapon system to include the number and type of maintainers required, and not mission capable maintenance and not mission capable supply times.

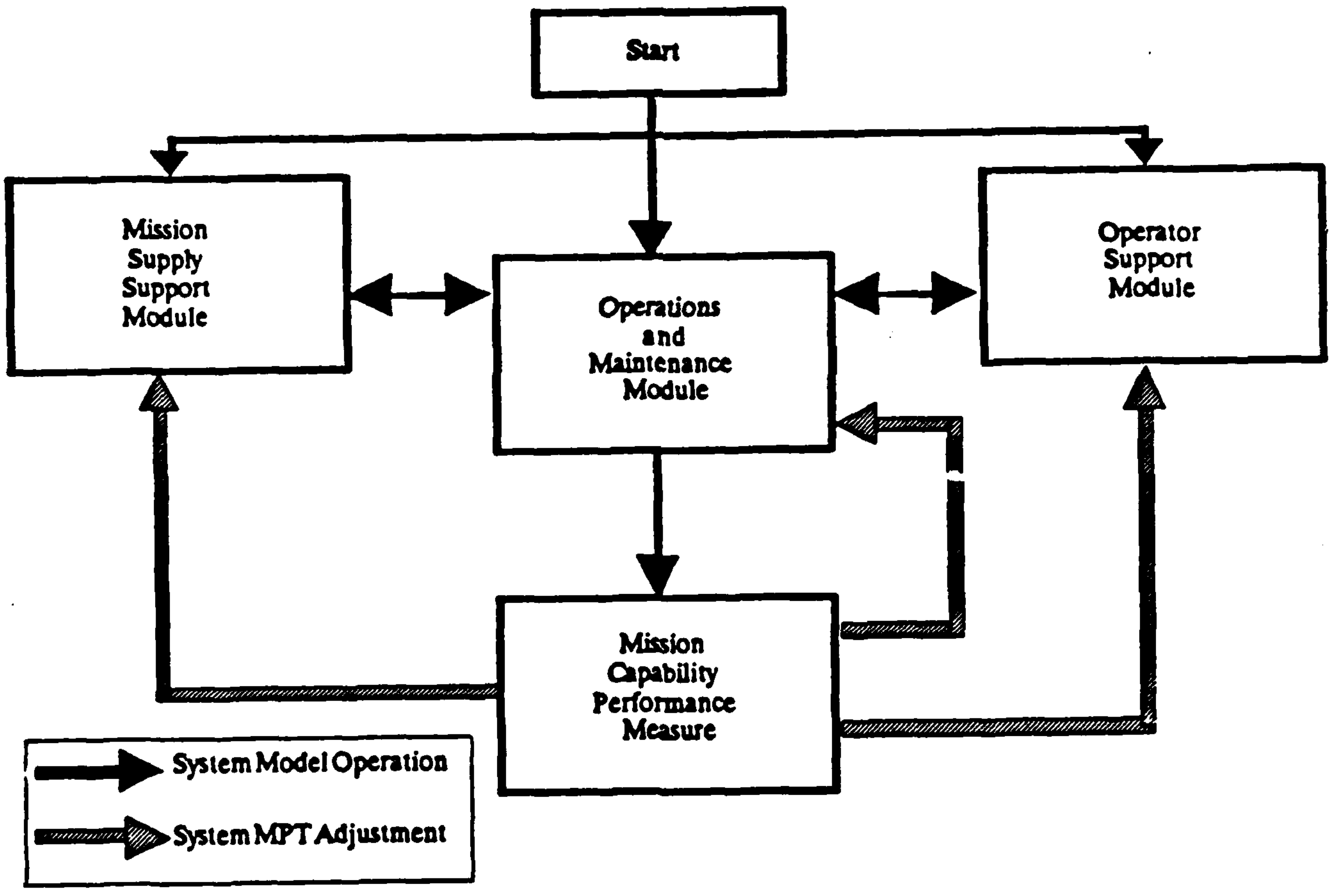


Figure 10. MANCAP overview (Phase II).

The operator and supply support modules are spreadsheet-based models that employ the outputs of the simulation to determine the operator and supply manpower required to support a specific mission capability. The operator support, the Class III and the Class V modules require mission specific inputs such as average flying hours per mission, number of missions per day per unit, and the number of weapon systems per mission. The Class IX module requires repair data to generate the Class IX manpower.

The output of the model application is mission capability measured in terms of the average number of weapon systems launched, average weapon systems completing the mission, and average operating hours per weapon system. The model allows the analyst to compare the model mission capability and associated manpower with the expected mission capability and manpower. Additional analyses, using either all or some of the three modules, can be conducted to determine the sensitivity of mission performance to various parameters.

Step 5 - Apply MANCAP to the LHX. As discussed previously, application of the MANCAP model to the LHX was done concurrently with and was an integral part of the method development to ensure that LHX specific manpower issues were addressed by the model. The results of the LHX analyses were reported in earlier reports and briefings. Thus, the discussion of the MANCAP application is focused on topics which further illustrate the method, not the results of the analysis. The model was implemented to establish a LHX base case unit capability using the LHX RAM factor goals, the LHX aviation assets in a LID with the appropriate unit mission scenario, and a seven day mission requirement.

The operating organizations were the Aviation Section in the Headquarters and Headquarters Company (HHC) of the CAB, the Air Reconnaissance Troops (ARTs) of the Air Reconnaissance Squadron (ARS), and the AHCs of the Attack Helicopter Battalion (AHB). The mission scenarios were taken from the mission profiles in the LHX RAM Rationale Report (USAAVNC, 1985c) with the exception of the utility mission scenario. The attack mission scenario consisted of two 3-hour missions performed back-to-back with eight aircraft each. The reconnaissance (recon) mission scenario consisted of two missions, one with five helicopters, the other with two helicopters, with the second mission launch occurring 1.8 hours after the first mission launch. For both missions, the mission duration was 3 hours. The utility mission scenario consisted of a series of continuous 3-hour missions with three aircraft each. Figure 11 illustrates the different mission scenarios used in the modeling effort.

For the attack mission scenario, four cycles of 18 hours each are used to obtain mission performance data for a period of 3 days. The utility and the recon mission scenarios simulated helicopter performance for three cycles of 18-hour periods for a total performance period of 3 days.

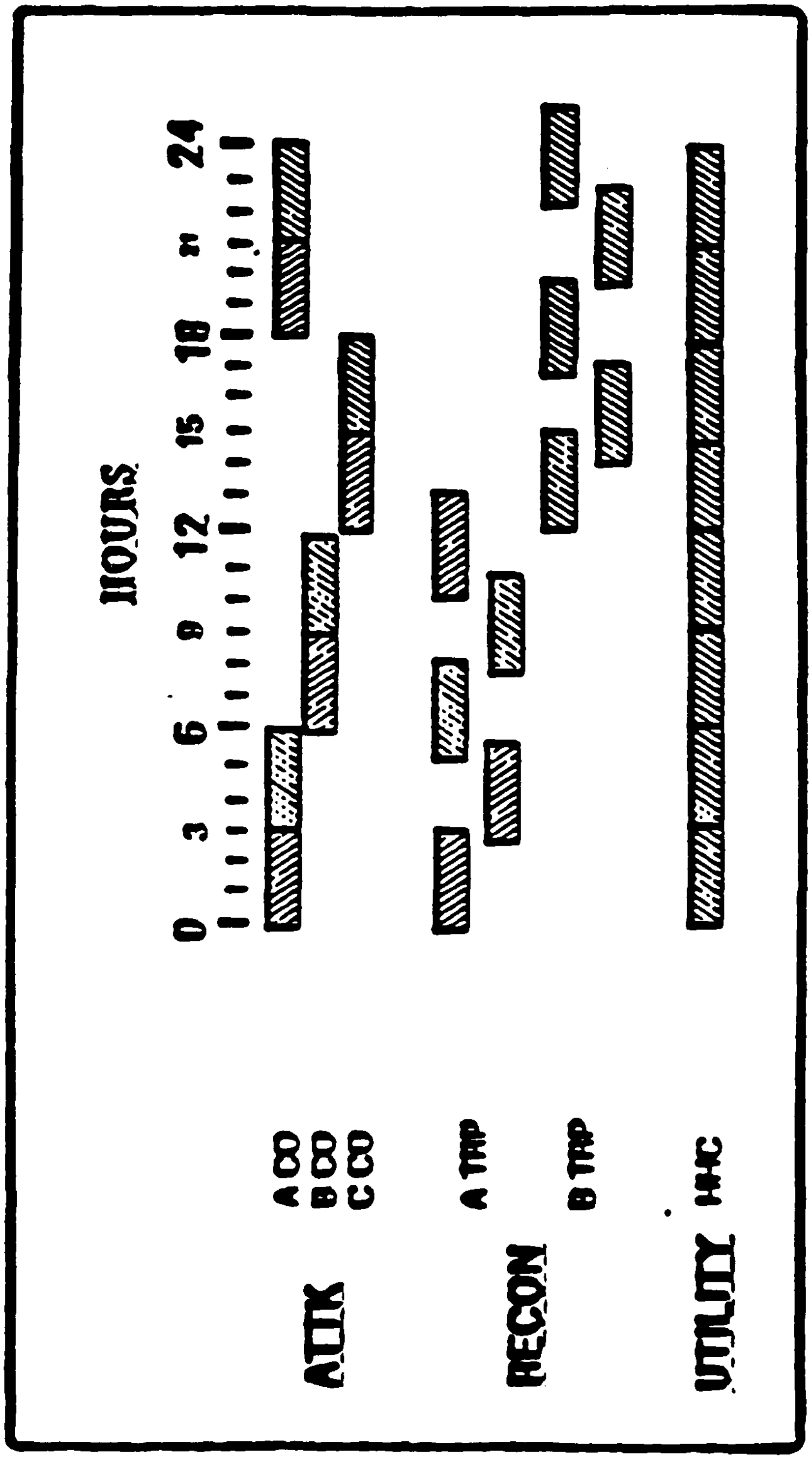


Figure 11. LHX mission profiles.

The performance period of 3 days was determined to be sufficient to achieve a steady state for each of the three mission scenarios because the differences in aircraft availability and average flying hours between performance periods of 3 and 7 days were minor and appeared to be due to differences in the random numbers used in the simulation process.

Class III and Class V supply support to the CAB are provided by the Class III and V Platoon of the HHC CAB. The Class III and V Platoon deploys its assets in various Forward Arming and Refueling Points (FARPs) as determined by the tactical situation and the available authorized equipment. Class III supply is provided to the Class III and V Platoon by the HSC of the Supply and Transportation Battalion (S&T BN) in the Division Support Command (DISCOM). FM 1-104 (Headquarters, Department of the Army [HQS, DA], 1985) states that when determining the fuel requirements for a unit, 100% helicopter availability is assumed. Therefore, determination of LHX fuel requirements was not dependent on LHX availability but on average mission duration, number of LHX per mission, and fuel consumption rates. FM 1-104 (HQS, DA, 1985) also states that refueling operations require one person to operate a pump and one person to operate a nozzle. For this analysis, it was assumed that refueling operations were accomplished simultaneously for all mission aircraft. Given these constraints, the LHX Class III manpower requirement for the Class III and V Platoon was based on the number of aircraft per mission and the refueling equipment utilized.

The LHX Class III spreadsheet is a "what if" tool to assess the viability of various FARP configurations and is based on the total fuel consumption per mission and the required replenishment capability. The total fuel consumption per mission was determined by the average flying hours, the number of helicopters per mission, and the fuel consumption rate per LHX. The replenishment capability is the amount of fuel that must be in the system in addition to the fuel at the FARP in order to sustain refueling operations. The total manpower required was then determined interactively from the amount of equipment and manpower required to refuel the selected mission and resupply the FARP. The placement of equipment and manpower can be varied to determine the refueling capabilities of the FARP given various combinations of equipment and different operating scenarios.

Class V supply is provided to the Class III and V Platoon by the Ammunition Transfer Point (ATP) Section of the Forward Support Company (FSC), S&T BN. FM 1-104 (HQS, DA, 1985) and the LHX Full Scale Development (FSD) Request for Proposal (RFP) (U.S. Army Aviation Systems Command [USAAVSCOM], 1986c) specify that rearming operations require two personnel per aircraft and assume 100% helicopter availability. Given these constraints, the LHX Class V spreadsheet determined the manpower requirements for the Class III and V Platoon based upon the number of helicopters per mission and mission cycle.

The LHX Class V spreadsheet also determines the manpower requirements for the ATP section based on the ATP Section workload and the total LHX ammunition requirements. An ATP section is authorized currently eight personnel (MOS 55B) and has a handling capacity of 275 tons of ammunition daily. The LHX ammunition requirements inputs included the total number of aircraft per mission, and the types and the weights of the ammunition required per day. The ammunition requirements were aggregated by unit types to determine the manpower required of the ATP Section to support the various LHX units.

Class IX supply is provided to aviation units through the PLL at the owning unit and through the ASL or shop stock located in the AMC of the DISCOM. The LHX Class IX spreadsheet computes manpower requirements based on the number of requisitions processed per day as determined from the operations and maintenance module and the supply manpower authorization criteria (MACRIT) unit of work. The total number of requisitions processed at the PLL level was determined on the basis of the number of maintenance actions requiring parts at the owning unit or its headquarters level. The total number of requisitions processed at the AMC was based on the total LHX requisitions processed within the division. The MACRIT work unit is expressed in lines of supply per man. Therefore, it was necessary to convert lines of supply to requisitions processed per day.

The three modules of the MANCAP model were first applied to each of the mission profiles assuming the availability of the authorized maintenance personnel as specified in the LHX RAM Rationale Report (USAAVNC, 1985c). These initial applications served as baselines from which sensitivity analyses were run to investigate potential personnel reductions and their impact on LHX mission capability.

<u>Evaluation of Phase II</u>

The MANCAP model provides a rapid and flexible tool to investigate manpower requirements associated with a particular mission capability. The attributes in the model that set it apart from existing models and methods are:

1. Accommodation of both mean time between mission affecting failures and MTBEMA;

2. Determination of mission capability in terms of the degree of fulfillment of a specific requirement at a specific time;

3. Determination of the maintenance delays awaiting personnel caused by the irregular presentation of workload; and

4. Identification of the number of personnel required by MOS by location.

The fidelity of the simulation is enhanced by accounting for both MAFs and essential maintenance actions (EMAs) through the technique of sampling the exponential distribution of the mean of each type of failure to determine when a failure will occur in the mission sequence. This technique has the effect of distributing the maintenance events realistically through the simulation which in turn enables accurate identification of workload and delays with respect to time. It also permits the identification of the level of accomplishment of a specific mission.

The ability to determine mission capability in terms of specific time sensitive mission scenarios provides two significant benefits. First, it enables requirements analysts to evaluate the direct opposition that can be brought to bear on the threat. Unlike the normal statement of weapon system availability which is expressed as an average attained by the entire fleet under a generic set of conditions which only provides a 50% assurance of attainment, MANCAP more precisely identifies how many weapons systems are operated successfully by which organization under a set of mission requirements peculiar to that organization. It also identifies when a weapon system became non-operational. This is the second major benefit of the model in that a distributed presentation of work to the maintenance support system enables the investigation of delays awaiting maintenance personnel.

The identification of where, when, and how long delays awaiting maintenance personnel occur is extremely useful to manpower and force structure analysts. It facilitates optimization of organizational strengths, structure, and disposition on the battlefield by allowing the analyst to perform a series of "what if" analyses to determine the mission capability resulting from varied combinations of strengths, structures, and battlefield disposition.

Another important element of the analytic capability of the model is the identification of the work performed by each MOS at each location. The individual workload enables manpower and force structure analysts to identify candidates for manipulation during "what if" analyses. For example, a delay awaiting personnel may be eliminated by relocating an under utilized manpower resource from a location without delays to the location experiencing the delay.

The supply support module provides an estimate of the manpower and equipment required to support a given mission scenario and enables the analyst to evaluate the effect of supply requirements on mission capability determined by the operations and maintenance module. Additionally, sensitivity analyses can be used to determine the positioning of equipment and personnel to most efficiently perform supply operations.

The operator support module provides the ability to determine the effect of system operations on manpower requirements for operator personnel.

Phase II succeeded in reducing the limitations of the approach developed in the Phase I effort and provided additional opportunities for expansion. The generic and flexible nature of the MANCAP model made it appropriate to a wide variety of manpower investigations to include further investigations of the LHX, other weapon systems, and other dimensions of the total system, such as doctrine and force structure. The most immediate application was to extend the investigation of the comparability of the LHX with predecessor systems by exercising the predecessors in the model in the context of comparable mission scenarios.

Extension to the predecessor systems would allow for further development of the MANCAP model and would serve as a step toward validating the MANCAP model because it would calibrate the model to existing systems that, in turn, would enable comparison of model outputs to historical data. In keeping with the results of the Phase II effort, it was decided to continue into a third phase of MANCAP method development by applying the model to the more complex organizational structure of predecessor systems.

Phase III: Application of MANCAP Method to Predecessor Systems

Introduction

The third phase of the effort was to develop automated models to provide unit manpower estimates for a weapon system by analyzing over time the relationships among unit mission capability; RAM supply concepts; and maintenance concepts. In the preceding phases the MANCAP model was developed and applied to the LHX. As a result of the success of the previous efforts, Phase III was initiated to enhance the MANCAP model by applying it in a comparability analysis of the LHX and its predecessor systems operating in comparable mission scenarios.

Background. The MANCAP model developed in Phase II consisted of three computer-based modules. One module was a computer simulation designed to run on an Apple MacIntosh. The other two consisted of spreadsheet-based models which operate on an IBM PC or PC compatible equipment. The combination of these modules provided the ability to output accurate specific mission capability data for a developing weapon system in less than 1 hour at a fraction of the cost associated with running such a model on a mini or mainframe computer.

Research Objectives. The primary objective of Phase III was to expand the analytical capability of the Phase II model to provide a means of comparing directly the mission capability of the proposed LHX system to predecessor systems, the AH-1 and OH-58. In this phase, the MANCAP model was applied to the same

organizational elements as were addressed in Phase II with the exception that the units were equipped with predecessor aircraft. Personnel and mission scenarios were adjusted appropriately to conform to the requirements of those aircraft.

An additional objective of the effort was to convert the model software, which in its previous state ran on an Apple Macintosh computer, into a programming language suitable for operating on an IBM PC or compatible equipment. The conversion was undertaken because most Army microcomputers are IBM PC compatible. The conversion of the model provided more users accessibility to the model for specific applications or sensitivity analyses.

This application also served as a step toward validating the MANCAP model because it calibrated the model to an existing system that enabled comparison of model outputs to historical data or to current activities such as the U.S. Army Aviation Logistics School (USAALS) proposed MAXFLY program.

Research Overview

Applying the MANCAP model to the LHX predecessor system was accomplished by holding the interaction of the model elements constant and changing only those parameters that were inherent in the predecessor. The three modules and their interaction operate as they did in Phase II in that the operations and maintenance module is a Monte Carlo simulation, and the operator and supply support modules are spreadsheet-based, expected value-models. When exercised concurrently, the outputs provide a measure of mission capability expressed in terms of average weapon systems starting the mission, average weapon systems completing the mission, average hours operated per weapon system, and the manpower required to achieve the desired mission capability. Manpower is given in terms of the number of personnel required in each unit to support the mission by MOS.

The application of the MANCAP model to the predecessor systems required modification of the mission profiles used in Phase II to accommodate the different combinations of weapon systems (AH-1 and OH-58), and identification of personnel resources provided by the LID TOE to support those weapon systems. The model was then modified where necessary, to reflect these organizational and system differences.

The approach used to modify the MANCAP Model for Phase III was the same as in Phase II. The model was defined in terms of assumptions and rules. Those organizational and doctrinal characteristics that are true generally throughout the U.S. Army were considered assumptions and were embedded firmly in the structure of the model as fixed parameters. Total system characteristics that are relatively fixed, but are not as generic as the assumptions, were considered rules. Rule changes are semi-fixed parameters and can be accommodated by minor re-

programming of the models. The remaining characteristics may change frequently and were categorized as interactive parameters.

As a result of the change in hardware, some further modifications to the program and model structure were required. Additional modifications were also made, where feasible, to improve the performance of the model, such as a reduced run time or an increase in the number of interactive parameters. Only those structural modifications that were required and did not affect the outcome of the model were made.

Steps 1, 2, and 3 of the research approach employed in the Phase II effort were unchanged for this effort. Therefore, the discussion of the research method in the succeeding paragraphs begins with Step 4, develop computer-based model. Step 5, apply model to the predecessor systems, focuses on the methodological implications of the application rather than the results since the results have been reported in earlier presentations and reports.

Step 4 - Develop Computer-Based Model. The development of the model was driven by the changes resulting from the system differences between the LHX and the AH-1 and OH-58 aircraft and by the changes resulting from the hardware conversion (Apple to IBM PC compatable). Specifically, the use of multiple weapon system types required modifications to the operations and maintenance module. The operator and supply support modules remain unchanged from the Phase II effort.

The operations and maintenance simulation was re-programmed on an IBM PC compatible microcomputer using Turbo PASCAL. The PC version of the simulation can be easily modified due to the inherent modularity of Turbo PASCAL. Specifically, the structure of the simulation is comprised of several subroutines that can be modified individually without requiring modification to the remaining subroutines.

The structure of the operations and maintenance module consists of six major subroutines that are called by the simulation in a progressive fashion. Figure 12 displays the simulation program structure to include the six major subroutines and their associated lower level subroutines. The six subroutines are:

- Setup Routine
- Mission Cycle
- Gen Events
- Determine Delta "t"
- Adjust Event Lists
- Move System Objects

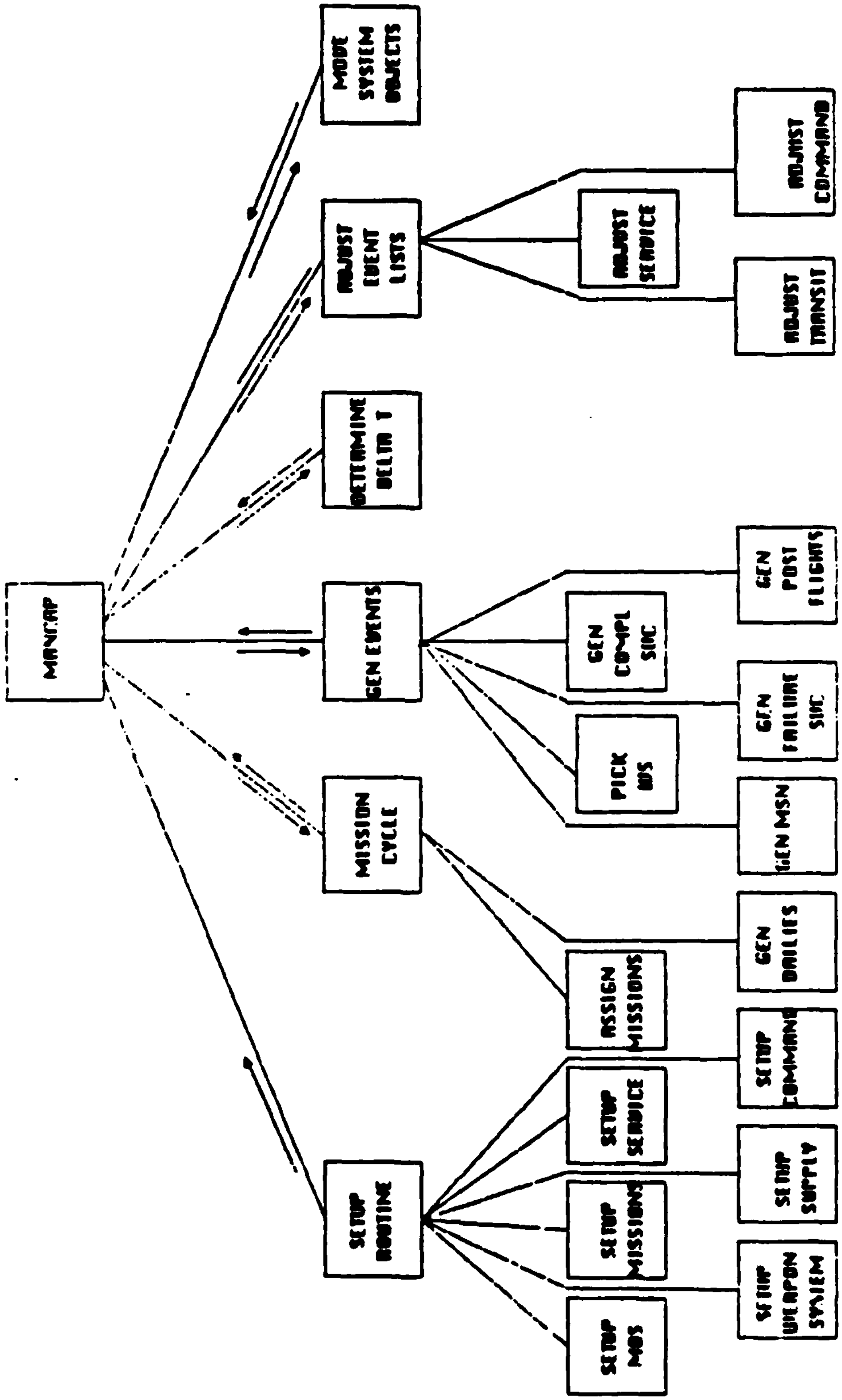


Figure 12. MANCAP program structure.

The first two subroutines, Setup Routine and Mission Cycle, set up the simulation. In Setup Routine, the weapon systems, MOS, mission, service, command, and supply organization parameters are initialized. The subroutine, Mission Cycle, is a setup routine that assigns missions to command organizations and generates daily inspections for the weapon system in each organization. The assignment of missions includes specification of mission durations, the mix of aircraft for each mission, and the launch intervals.

The simulation then progresses to Gen Events which generates the initial set of events for each aircraft. Based on the mission profile, Gen Events is further subdivided into subroutines that select the weapon systems to perform each mission and generate missions, failure events, mission completion events, and post flights. For each event generated, the simulation stores the location of the weapon system, the time required to perform the event, the priority of the event, and the MOS required, if any. Event priorities remain semi-fixed parameters as in the Apple MacIntosh version.

Once all events for each weapon system have been generated, the subroutine, Determine Delta 't', is called to compare each of the events and to determine which event is to occur first. After determining the change in the simulation time for the first occurring event, the simulation then calls the subroutine, Adjust Event Lists to update the simulation clock for all remaining events. The subroutine, Move System Objects, is called to update the location of each weapon system object and MOS object based upon the adjusted list of events. The process of determining changes in the simulation clock, adjusting events, and moving system objects continues until the simulation reaches the end of simulation time specified in the set up of the simulation.

Simulation Differences from Phase II Model

There are four major differences between the model structure of the Turbo PASCAL version and the Macintosh version of the simulation. The primary difference in the operation of the two models is that the model developed in Phase II only exercises one mission profile at a time in the simulation. The current model is constrained only by the memory of the computer when determining the maximum number of mission profiles to perform missions simultaneously. Therefore, the capability now exists to simulate the maintenance operations of the AMC truly, based upon the total workload generated by the operating organizations performing missions simultaneously and placing simultaneous demands on the AMC.

The second deviation from the Phase II model is the method used for generating failure times. In the previous effort, failure times were generated after a weapon system had been selected for a mission. The failure times were sampled for each mission and if the failure time occurred after completion of the

mission, that time was zeroed and the failure time was re-sampled for the next mission. In this effort, the simulation samples for each system determined the operational hours at which the next MAF and EMA will occur. The simulation then progresses and when a system accrues the first of those operating hours, it will fail. Both clocks are then reset using the sampling process.

Another area of modification is the data storage technique used for the Phase III effort. The model developed in Phase II had a string variable associated with each weapon system. The string variable acted as a "genetic code" for the weapon system and provided all mission data, repair data, and supply data for each individual aircraft. In the Phase III model, the data are stored in terms of events. An event occurs whenever the characteristics of the mission change such as the occurrence of a failure, the completion of a mission, or a request for a part. The model stores each event as it occurs with the associated weapon system, the location of the weapon system, the status and priority of the aircraft, and the MOS required. As the simulation progresses it tracks past events, performs the current event, and monitors the future events.

The final difference is the classification of the attributes of the revised model. While most of the attributes were the same rules and assumptions discussed in the previous section, Phase II: Method Development, the classification of the rules as fixed, semi-fixed, and interactive changed in some instances. For example, the number and types of repairer personnel were made interactive[1]. The operating and support organizational structure was also made interactive as well as the cycle length. Appendix A of this report presents the list of the attributes classified as assumptions, fixed, semi-fixed, or interactive parameters.

<u>Step 5 - Applying MANCAP to Predecessor Systems</u>. The systems modeled in this effort, like the Phase II effort, were the aircraft owning organizations in the LID's CAB that are scheduled to receive the LHX. These organizations included the Aviation Section of the HHC of the CAB, the ARTs of the ARS, and the AHB. In order to compare the mission capability of the LHX directly with its predecessor, mission profiles were held constant except that predecessor aircraft were exercised in the scenarios rather than the LHX.

In the LID, both the OH-58 and the AH-1 are to be replaced by the LHX SCAT. Mission profiles were developed that employed both aircraft types and were comparable to those employed for the LHX application in Phase II. Since the AHB and ARS are currently authorized the AH-1 and OH-58 aircraft, the mission profiles

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[1]Interactive in the sense that the analyst must identify the appropriate subroutine that the interactive parameter resides, enter Turbo PASCAL and make the change to the subroutine, compile the program and then run the program to obtain the results.

developed for these organizations required a mix of these two type aircraft. Table 2 provides a comparison of the LHX mission complements to predecessor mission complements. As can be seen from the table, the attack and utility mission profiles for the predecessor aircraft each employs a single complement of aircraft. The reconnaissance profile employs two alternating complements. One cycle of the attack mission profile consists of six consecutive 3-hour missions with each company in turn flying two back-to-back missions. Since the attack mission is heavily dependent on the attack capabilities of the AH-1, a mission abort will occur if there are not any AH-1 aircraft available to begin a mission. One cycle of the reconnaissance mission profile consists of two companies flying five, 3-hour missions alternating from one complement to the other at 2.4 hour intervals. Figure 13 illustrates these two profiles and the associated aircraft requirements. The utility mission profile, illustrated in Figure 14 remains a three ship 3-hour back-to-back continuous mission but with the OH-58 exercised in the simulation instead of the LHX utility aircraft.

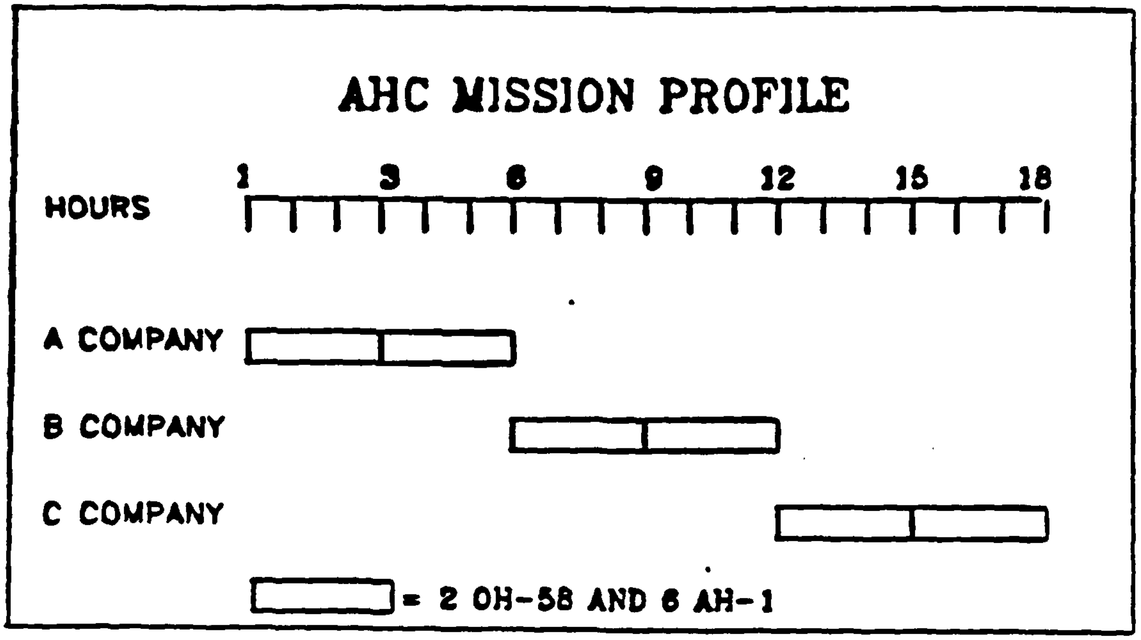
Table 2

Comparison of Mission Complements

Type	LHX Scenario	LHX Auth.	Predecessor Scenario	Predecessor Auth.
Attack	8 Scat	11 Scat	2 OH-58 6 AH-1	4 OH-58 7 AH-1
Recon1	5 Scat	10 Scat	4 OH-58 2 AH-1	6 OH-58 4 AH-1
Recon2	2 Scat		2 OH-58 1 AH-1	
Utility	3 Utility	6 Utility	3 OH-58	6 OH-58

Due to the different mix of aircraft, the model was adjusted to accommodate multiple sets of RAM characteristics and to compile the output data for two different aircraft types operating in one mission scenario.

The supply wait times used for the model application to the LHX and predecessor aircraft were those wait times specified in the LHX ALDT model given in the LHX RAM Rationale Report (USAAVNC, 1985c). These times were held constant (from the first two phases) for the predecessor application in order to isolate the differences brought about by the design characteristics of the predecessor aircraft being modeled.



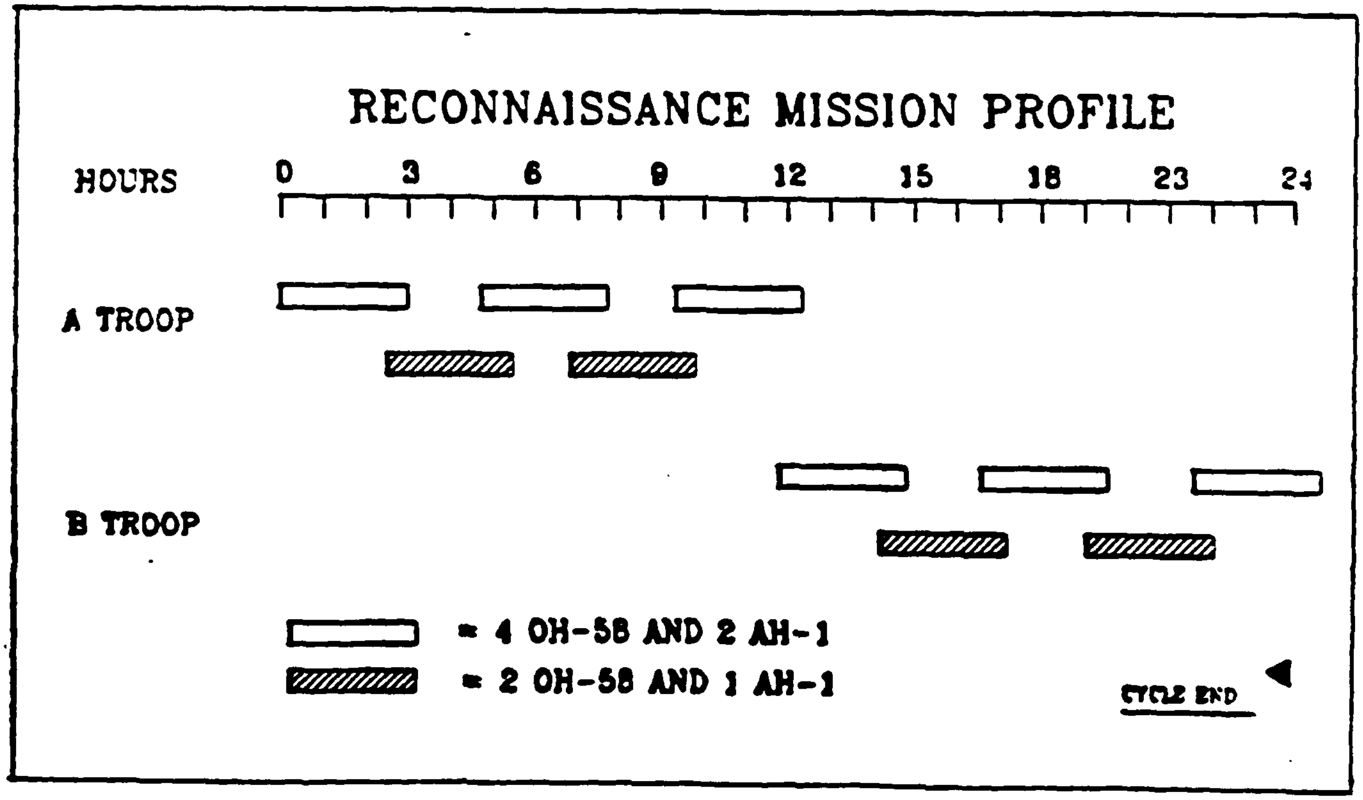


Figure 13. Predecessor attack and recon mission profiles.

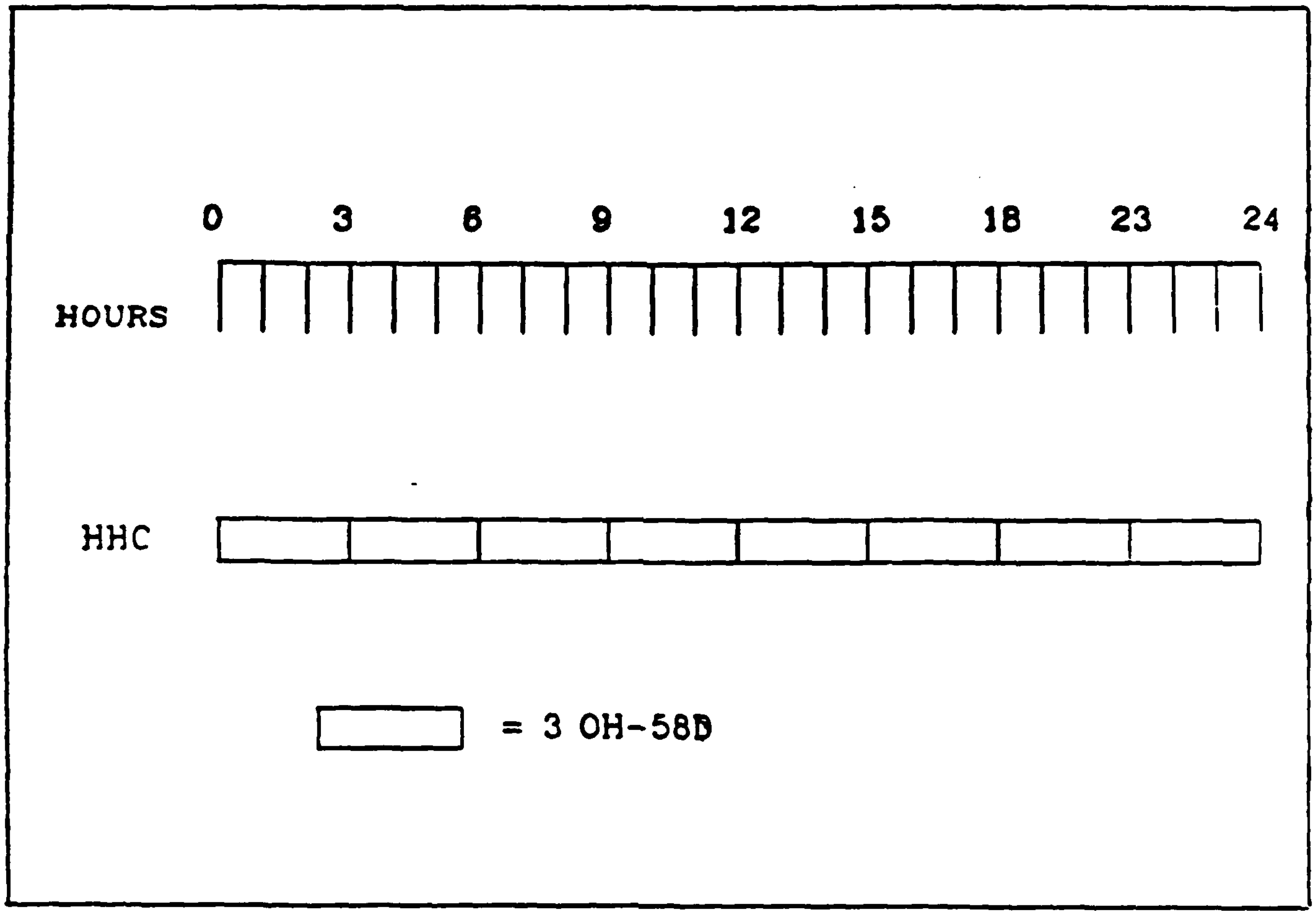


Figure 14. Predecessor utility mission profile.

Additional adjustments were made to the operating and support organizations as a result of the different aircraft types. The L series TOE was used to determine the numbers and types of personnel that are authorized to operate and support the three mission scenarios. Since it was assumed that there is one crew chief assigned per aircraft, the number of repairer MOS at the flight line was adjusted to reflect only one crew chief per aircraft. The additional repairers were allocated to the Level 2 service organizations, HSC, and Headquarters and Headquarters Troop, to perform non-flight line repairs. Any repairer MOS present at the second level of service that do not repair the weapon system being modeled were allocated to the AMC, the next highest service level. The maintenance workload was distributed among repairer MOS according to the probabilities derived from a combination of the AVUM and AVIM CSS LRI (logical region I) MARC factors based upon the Department of the Army (DA) flying hour program. The AVUM and AVIM factors were combined to approximate a 2LM structure similar to that proposed for the LHX. The maintenance man-hours per flight hour (MMH/FH) performed at the flight line was subtracted from the total MMH/FH expended to determine the number of MMH spent performing repairs above the flight line. The MARC factors were then used to calculate the percentage of repairs performed by each MOS above the flight line.

Initially, two runs of the simulation were performed to provide a basis for comparing LHX mission capability with the mission capability of its predecessor systems. The output data provided the inputs for the spreadsheet models to determine the supply support personnel and operator resources required to support the simulated mission capability. From the data obtained in the initial runs, sensitivity analyses were then performed in an attempt to reduce the manpower required to support the mission and to increase mission capability.

Modifications in the operator and support modules were minor and consisted of differences in input data to include fuel consumption rates, ammunition requirements, and operator requirements. The numbers and types of supply personnel were also determined from the L Series TOE, and therefore remain unchanged for this effort. Additionally, the same productivity per man (as for the LHX application) for Class IX operations was assumed for this effort.

The doctrinal constraints establishing work limitations and number of operators required per weapon system were re-evaluated for application of the models to the OH-58 and the AH-1. As a result, the operator support module was adjusted to incorporate the requirement of two pilots for the OH-58 and the AH-1 instead of the one pilot required for the LHX. Given the numbers of personnel authorized as dedicated pilots, crew rest limits will be exceeded if flying two pilot operations. Thus, staff aviation officers must fly a portion of the missions in order to perform the missions and remain within crew rest limitations.

Evaluation of Phase III

The MANCAP model is currently designed to operate on IBM PC compatible computers using Turbo PASCAL and Lotus 1-2-3. It provides a rapid and flexible tool to estimate the manpower requirements of a weapon system given a desired mission capability. In its current form, the model can be applied to systems employing multiple weapon systems operating under different mission scenarios requiring support of up to four different organizational levels. The model developed in Phase III clearly discounts the limitations of the earlier efforts and accomplishes the overall goals of the program. The program developed a method that estimates the maintenance manpower requirements early in the concept development phase of the acquisition process and provides analytic support to the LHX PM office by calculating expected manpower savings for maintenance personnel based upon LHX RAM data.

Specific contributions of the Phase III effort include the expansion of the model to incorporate the capability to simulate up to four different service levels and four different supply levels while exercising up to five different organizations in the simulation at any given time. The flexibility of the model to incorporate different organizational structures makes it applicable to a wide range of systems.

The current MANCAP model is also relatively fast and inexpensive to run. The Turbo PASCAL version of the model requires approximately 30 minutes[2] to run the three mission profiles through one three-day cycle iteration whereas the Apple BASIC version required approximately one hour to run one mission profile through a three-day cycle iteration. The only hardware requirements are the availability of a IBM PC compatible personal computer with 640K of RAM memory, a 360K or 1.2 MB floppy disk drive, and a hard disk with a minimum of 1 MB of free space. Software requirements include MS or PC DOS version 2.0 or greater, and Lotus 1-2-3 Version 2.0. Turbo Pascal Version 4.0 is required if modifications to the simulation are desired. Since MANCAP requires only minimal hardware and off-the-shelf software, it is relatively inexpensive to run. Sensitivity analyses can be run at a fraction of the cost of running such analyses on a main frame or mini computer.

The major advantages of this method are its speed and relatively low cost which make it extremely useful to the analyst particularly in performing "what if" analyses. The key to sustaining these advantages lies in the modular architecture and its interactive nature.

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[2]For a PC with a speed of 16 MHz. PCs having a slower speed will require a longer run time. Additional iterations are required for valid results.

As has been stated, MANCAP is intentionally generic and can be applied to most systems. Furthermore, application is not limited to weapon systems currently in the acquisition process. It can be applied equally as well to investigations into the manpower and mission capability cause and effect relationships of fielded weapons to quantify existing requirements, to investigate the ramifications of product improvements, or to investigate doctrinal or force structure changes.

Manpower Implications of the LHX Two-Level Maintenance Concept

Introduction

The organizational modeling effort was undertaken to develop a generic method to analyze maintenance manpower requirements early in the concept development phase of system acquisition programs. The 2LM project described in this section was designed to examine specifically the manpower implications of changing from a three-level to a two-level maintenance concept for organizations receiving the LHX. As originally conceptualized, the research effort would aid in defining the 2LM concept as well as examining the manpower implications of the new maintenance structure.

The 2LM research effort presented a classic effort in the problems inherent in conducting MANPRINT analyses in the early stages of a major system acquisition program. The failure of necessary data to become available within the period of performance of the research effort and the lack of consensus on the most appropriate baseline assumptions and data to be used for comparison of manpower savings for the LHX and the proposed 2LM concept, presented major challenges to the research team. As the research project evolved, the effort focused on methods for development of a strawman 2LM structure for units receiving the LHX, and analysis of factors underlying the variability in different LHX maintenance manpower estimates.

The remainder of this section describes the background, evolving research objectives, research method, and results of the 2LM project. The section ends with a critical review of results as compared to the original research objectives and a discussion of lessons learned for future MANPRINT analysis efforts related to changes in doctrine or organizational structure.

Background

Early in the development of the LHX program, a 2LM concept was mandated for the LHX. The LHX O&O Plan (USAAVNC, 1985b) specifies that the 2LM concept consists of two task levels: aviation user and depot maintenance. While the O&O Plan briefly defined the 2LM concept, it provided little detail on how the concept should be integrated with the LHX. In fact, there was some concern within the Army aviation community that a 2LM structure would degrade mission capability of LHX units.

In response to the questions and issues raised by the 2LM concept for the LHX, USAALS established a 2LM working group and initiated a 2LM study. The USAALS program was to be conducted in two phases: (1) an investigation of the impact of 2LM on the LHX and (2) an investigation of the impact of 2LM for the entire fleet. The LHX 2LM working group was charged to develop a working definition of 2LM for the LHX. The 2LM research effort was conducted in support of the USAALS program. To the extent possible, this effort incorporated the 2LM working group's definition. An overview of the definition of 2LM maintenance which evolved during the course of the present project is provided below.

Attributes

The LHX 2LM concept is comprised of user maintenance and depot maintenance. User maintenance consists of all on-aircraft repair tasks requiring no special tools or automatic test equipment. Depot level maintenance includes all off-system repairs and major on-system repairs. Maintenance at depot level is to be performed primarily in support of the supply system with limited back-up support to user organizations. The concept relies on increased system reliability to limit the frequency of depot repairs and use of effective BIT/BITE and the line replaceable unit (LRU) maintenance concept to simplify and then the time limit required for user tasks.

Under the 2LM concept, the preponderance of existing AVIM tasks are to be combined with AVUM tasks and categorized as user maintenance. A small portion of the actions performed at AVIM will be apportioned to depot and a small portion will be eliminated. The elimination of tasks is due to advancements in technology and the LRU concept. AVIM tasks are currently performed by the Aviation Maintenance Battalion (AMB). Theoretically, the AMB would be dissolved under a 2LM concept. However, the USAALS 2LM working group suggested that a maintenance activity remain in a two-level system to perform back-up user maintenance and support to non-divisional organizations. That activity would also perform evacuation of non-mission capable aircraft to repair sites to maintain high mobility in aviation units.

In the existing three-level structure, actions are performed at the various levels of maintenance based upon time to repair and equipment. That is, long duration maintenance actions are evacuated to the higher user maintenance unit to preserve the mobility of the owning unit. Repairs requiring special tools and test equipment are generally allocated to AVIM to avoid costly redundancies of maintaining the equipment throughout the force structure. As noted above, the LHX RAM driven design goals coupled with the LRU concept and BIT/BITE are expected to reduce repair times drastically and eliminate the need for special tools; thus obviating the need for the existing third level. However, the remaining maintenance categories are not

geographically constrained. User functions may be performed external to the owning unit as far to the rear as depot. Depot activities may be required in theater, perhaps with maintenance teams occasionally operational as far forward as the LHX owning unit.

Expected Advantages

The purpose of employing a 2LM concept, as stated in the Integrated Logistic Support Plan (ILSP) (USAAVSCOM, 1985b), is to contribute to achieving the LHX program goal of a 40% reduction in maintenance manpower. The reduction of maintenance manpower is expected to be accomplished through the effective and efficient use of BIT/BITE, LRUs, and through the elimination or reduction of maintenance units. With only two levels of maintenance, it is expected that some maintenance activities will be reduced or eliminated, and thus the number of overhead personnel will also be decreased. Two organizational levels are also expected to reduce the frequency of aircraft transfers between maintenance activities which will lessen manpower requirements, and administrative and logistics delay time.

BIT/BITE is intended to eliminate the need for off-aircraft test and measurement diagnostic equipment (TMDE) and automatic test equipment (ATE). If BIT/BITE performs as designed, a reduction is expected in the skill requirements for maintenance personnel who are to operate and maintain the current inventory of off-aircraft test equipment.

The LRU concept eliminates the need for piece-part repair except in support of the supply system. Therefore, the skills required of maintenance personnel below depot should be greatly reduced which should result in reduced training requirements for personnel performing only user maintenance.

In addition to personnel reductions, these maintenance concepts are expected to alleviate the problem of skill creep that has been associated with new weapon systems employing large amounts of increased technology. For the LHX, the largest portion of technologically demanding maintenance tasks will be removed to depot which should result in reduced training requirements for personnel in user organizations. Currently, all maintenance personnel are trained to the same skill level regardless of organization affiliation. If all technologically demanding tasks are removed to depot organizations, training should be reduced in user organizations without increasing the training required in depot organizations. Training time is also expected to be reduced in all maintenance organizations under the two-level concept due to the absence of TMDE and ATE.

Potential Risks

If the design goals for the LHX cannot be met, a 2LM concept has the potential to reduce aircraft availability due to the

reduced depth of organizations and personnel. Poor performance of BIT/BITE could increase the depot workload to the point that repairs cannot be accomplished in a timely manner. Inadequate depot support would in turn overtax the supply system.

Currently, AVIM organizations provide maintainer skills and equipment that have not historically been dedicated solely to the maintenance of airframes. Instead, they have routinely been used to support maintenance of the supply system, particularly direct exchange accounts. The elimination of maintenance in support of the supply system below depot may also place an additional burden on logistics lines of communication which may ultimately impair LHX mission capability.

Research Objectives

The LHX joint MANPRINT working group (JMWG) requested that ARI sponsor a review of the LHX 2LM concept as part of the MANPRINT program. Specifically, the JMWG requested that a research effort be conducted to assess the maintenance MPT requirements for the LHX operating under a 2LM concept.

As originally formulated, the 2LM project had several research objectives. The first of these objectives was to aid in the definition of the 2LM concept further. As part of this objective, the research team was also asked to develop a strawman maintenance structure for units receiving the LHX. The maintenance structure was to be designed for analysis of the 2LM concept in the AAD.

The second objective of the research effort was to determine the manpower requirements for the LHX operating under a 2LM structure. The projected manpower requirements would be compared with the existing maintenance capability in the AAD.

The final research objective was to compare the maintenance manpower requirements developed in this project with those in other LHX projects to contrast their manpower, implications and to delineate the differences in their assumptions.

Initial Assumptions

To project the aviation maintenance architecture for the LHX given a 2LM structure and then compare it to the existing architecture, it was necessary to select a representative organization for which a description could be made. For this effort, it was agreed upon by the JMWG that the AAD would be used. The AAD was chosen because it is a representative organization receiving a large portion of LHX aircraft while at the same time continuing to maintain a substantial number of existing systems. The selection of the AAD as the model organization provides an opportunity to examine both the impacts of 2LM on the LHX and also the ability of the LHX employing a 2LM system to coexist with existing systems.

Approach

The approach used to determine the manpower requirements of the LHX and the maintenance manpower capabilities of the AAD consisted of a series of four steps:

1. Literature review;

2. Quantification of manpower authorizations in a 3LM system;

3. Develop maintenance manpower capability of the existing AAD employing a 2LM concept; and

4. Develop maintenance manpower required for LHX under 2LM.

The four steps listed above provided the research team with the ability to make comparisons between the 2LM manpower requirements of the LHX and the 3LM manpower requirements developed for the AAD with current aircraft. Comparisons were also made between the 2LM manpower required for the LHX and the estimates developed in LHX HARDMAN analyses and LHX COEA. The comparisons made addressed the manpower, personnel, and training implications under the proposed 2LM structure.

Literature Review. The first step in developing the maintenance manpower requirements was to review the existing maintenance doctrine to determine the relationships between existing Army doctrine, existing mission capability, and existing manpower and personnel authorizations. Included was a review of the existing AOE AAD TOE to determine the numbers and types of maintenance personnel and equipment authorized under the existing system.

The AOE AAD TOE provides the AVUM and AVIM support to the division under the current three-level system. AVUM support is organic to division organizations in the form of crew chiefs or repairers authorized in each organization. AVIM support is obtained for division aircraft from the AMB which has two AMCs to support the division's aircraft. The AMB also has an HSC which contains the battalion headquarters and an Aircraft Supply Platoon which is responsible for technical supply of aircraft repair parts and associated hardware and bulk materials in support of the division's aviation maintenance activities. Table 3 presents the numbers and types of maintenance MOS authorized for each organization in the AAD.

Table 3

Air Assault Division TOE 01202L000

MOS	MEDICAL BN	COMBAT AVN BN (UH-60A)	COMBAT AVN BN (CH-47C)	COMMAND AVN BN	ATTACK BN	AIR RECON SQDN	AVIATION MAINT BN
35K	2	5	8	8	6	6	6
35L							24
35M							14
35P		1	2	1	1	1	11
35R							30
66J					1	1	4
66N				8	1		3
66R							
66S							
66T	3	11				3	9
66U			24				7
66V				2	2	4	5
66Y					4	3	7
67H							
67N			4	61	6		6
67R							
67S							
67T	17	116		8		22	43
67U			160				36
67V				20	31	55	18
67Y				4	40	36	28
67Z		5	4	5	5	5	7
68B	1	3	4	3	2	3	32
68D	1	2	10	2	2	3	20
68F	1		4		1	1	14
68G	1	3	4	4	3	5	32
68H			2				6
68J					8	8	32
68K		1	2	1	1	1	3
68M			2		7	7	24

The AAD currently supports a total of 386 aircraft consisting of 116 UH-60A, 32 CH-47C, 47 UH-1H, 91 OH-58A, and 100 AH-1S. These aircraft are distributed among a Medical Battalion, two UH-60A Combat Aviation Battalions, a CH-47C Combat Aviation Battalion, four Attack Helicopter Battalions, an Air Reconnaissance Squadron, and the Aviation Maintenance Battalion. Table 4 displays the current allocation of each type aircraft in each organization of the AAD.

Table 4

Aircraft Distribution in AAD

AIRCRAFT	MEDICAL BN	COMBAT AVN BN (UH-60A)	COMBAT AVN BN (CH-47C)	COMMAND AVN BN	ATTACK BN	AIR RECON SQDN	AVIATION MAINT BN	DIV TOTAL
UH-60A	12	45				10	4	71
CH-47C			32					32
UH-1H			2	30	3			35
OH-58A				15	13	24		52
AH-1S					21	16		
37								
TOTAL	12	45	34	45	37	50	4	227
LHX* Distribution	12	0	2	45	34	40	0	133

*The LHX will replace UH-1, AH-1, and OH-58 aircraft.

<u>Quantification of Manpower Requirements</u>. To establish the existing maintenance capability it was necessary to determine the available MMH per day for each of the existing repairer MOSs authorized by the AAD TOE. The available MMH per day were determined for each organization owning aircraft in the division. The direct maintenance time available per man was assumed to be 3.4 hours for AVUM and 3.9 hours for AVIM organizations as specified in the LHX RAM Rationale Report (USAAVNC, 1987). The available MMH were then summed to determine the existing maintenance capability.

The MMH available per LHX for each MOS in each organization were calculated by multiplying the number of personnel in each organization receiving the LHX and dividing it by the total number of aircraft authorized for the organization. The portion of AMB personnel for each MOS available to work on the

organization's aircraft was also calculated by multiplying the number of authorized personnel by the total number of aircraft to be replaced and then dividing by the total aircraft authorized in the AAD.

To determine the available productive man-hours per day, the portion of MMH for each organization were multiplied by the direct MMH authorized. Per LHX RAM Rationale Report (USAAVNC, 1987), the direct productive man-hours per day at AVUM are 3.4 hours for LRI, Combat Support (CS). The direct productive man-hours per day at AVIM in LRI, CSS is 3.9 hours. The only CSS unit is the AMB of the DISCOM. Each organization in the CAB of the AAD is considered a CS organization. The productive available MMH/day for CS and CSS organizations were summed to derive the total maintenance manpower capability for each MOS.

Similarly, the procedure was repeated to calculate the productive MMH/day available for each MOS authorized to perform maintenance on other than LHX aircraft. The combination of the maintenance manpower available for non-LHX aircraft and the maintenance manpower available for aircraft to be replaced by the LHX represents the total productive maintenance manpower capability in the AAD assuming a 2LM structure. Table 5 presents the numbers and types of maintenance personnel authorized in the AAD and the maintenance capability by type MOS for LHX aircraft, non-LHX aircraft, and the total AAD.

Estimate of LHX Requirements. The maintenance manpower required to support the LHX in the AAD was determined using both the current MARC to support DA wartime flying hours and the MAA flying hours mandated for the LHX. Both sets of calculations were done to compare the manning requirements resulting from the research effort to the estimates developed in HARDMAN comparability analyses.

The LHX maintenance manpower requirements were determined by multiplying the total number of LHX aircraft programmed for the AAD, as specified by the Draft LHX Distribution Plan (U.S. Army, 1986), by both the DA and MAA flying hour program to determine the total number of LHX flying hours per day. The LHX RAM Rationale Report (USAAVNC, 1987) specified a maintenance ratio of 2.6 MMH/FH for the LHX. The maintenance ratio was then multiplied by the total number of flying hours to determine the total number of maintenance man-hours required per day for the LHX.

After estimating the LHX maintenance manpower requirements, the research team conducted a number of analyses comparing the estimated requirements to expected AAD maintenance capability and maintenance requirements calculated in other LHX projects. The results of these analyses are described in the paragraphs below.

Table 5

Maintenance Manpower Available for LHX and Non-LHX Aircraft in AAD

MOS	PERSONNEL	MMH AVAIL FOR LHX	MMH AVAIL FOR NON-LHX	TOTAL MMH AVAIL FOR AAD
35K	64	141.332	79.268	220.600
35L	24	57.712	35.888	93.600
35M	14	33.665	20.935	54.600
35P	21	45.469	31.431	76.900
35R	30	72.140	44.860	117.000
66J	9	24.836	7.764	32.600
66N	15	46.911	5.589	52.500
66R	0	0.000	0.000	0.000
66S	0	0.000	0.000	0.000
66T	37	40.002	90.298	130.300
66U	31	21.633	87.267	108.900
66V	19	54.698	12.402	67.100
66Y	26	74.982	16.918	91.900
67H	0	0.000	0.000	0.000
67N	95	297.612	28.388	326.000
67R	0	0.000	0.000	0.000
67S	0	0.000	0.000	0.000
67T	322	248.241	868.059	1116.300
67U	196	118.568	565.832	684.400
67V	217	648.300	98.500	746.800
67Y	228	678.742	110.458	789.200
67Z	51	110.719	66.181	176.900
68B	57	124.504	85.296	209.800
68D	48	93.448	79.752	173.200
68F	24	53.083	35.517	88.600
68G	64	145.841	87.759	233.600
68H	8	14.828	15.372	30.200
68J	72	198.688	62.112	260.800
68K	13	26.231	19.469	45.700
68M	61	164.633	54.767	219.400
TOTAL	1746	3536.816	2610.084	6146.900

TOTAL NON-LHX AIRCRAFT	148.00
TOTAL AIRCRAFT IN AAD	386.00

Results and Discussion

The results of the calculations to estimate the LHX maintenance manpower requirements under a 2LM concept are presented in Table 6. This table provides the maintenance man-hours required per day to support the LHX flying both the DA and the MAA flying hour program.

Table 6

Maintenance Man-hours Required for LHX

Baseline	Annual Flying Hours	Maintenance Ratio	MMH/Day
DA	848	2.6	1437.66
MAA	2094	2.6	3550.06

The LHX estimate and the maintenance capability of the AAD were then compared to determine if the current structure of the AAD would support the LHX and the remaining non-LHX aircraft. The comparison included a discussion of the possible areas in which personnel reductions are possible in the current structure while maintaining the mission capability RAM goals.

Comparison of LHX Estimate and AAD Capability

The LHX estimates of maintenance manpower requirements vary in direct proportion to the flying hour programs. The MAA flying hour program is more than twice the DA flying hour program, therefore, the MAA manpower requirement could be assumed to be more than twice the DA requirement.

DA Wartime Estimate. The LHX estimate based upon the DA flying hour program results in a savings of 59% over the current capability as derived from the current manning of the AAD. The 238 LHX aircraft are estimated to require 1,437.66 MMH/day whereas under the existing structure, the AAD is capable of performing direct maintenance of 3,536.82 man-hours per day on aircraft scheduled to be replaced by the LHX.

The savings is determined only for those personnel who are available and authorized to perform maintenance on aircraft being replaced by the LHX. It is assumed that those personnel available to perform maintenance for the LHX will be appropriately re-classified and retrained.

The overall maintenance capability of the AAD is 6,146.9 direct MMH/day of which 2,610.08 MMH/day are allocated to the performance of maintenance on non-LHX aircraft. A 59% reduction in the MMH requirements for the LHX enables a reduction of personnel, skills, and training requirements throughout the division. The reduction in maintenance manpower requirements is due to the significant decrease in maintenance actions required per flying hour for the LHX, as specified in the LHX RAM Rationale Report.

MAA Flying Hour Estimate. The estimate of LHX maintenance manpower required, based upon the Army Aviation MAA flying hour program, is more than currently authorized in the AOE AAD TOE. The total maintenance capability of the AAD was calculated to be 6,146.9 MMH/day with 2,610.08 MMH allocated to the repair of non-LHX aircraft scheduled to remain in the AAD with the fielding of the LHX. The LHX in the AAD requires a total of 3,550.06 MMH/day under the MAA flying hour program. This slightly exceeds the current capability allocated for LHX aircraft. This figure is not surprising since current manpower authorizations are based upon a DA wartime flying hour program of 780 flying hours per year for the AH-1S and 816 flying hours per year for the OH-58. The MAA flying hour program specifies 2,094 flying hours per year for the LHX which is more than twice the flying hours required by the DA flying hour program.

It should be noted that while the MAA specifies far more flying hours for the LHX than does the DA wartime estimate, the ILSP specifies a reduction in the maintenance manpower and personnel required for the LHX. It is not likely that the two objectives can be accomplished simultaneously.

Impact of 2LM on Other CSS. The reduction in the number of maintenance actions required for the LHX will not only result in a reduction of maintenance manpower required but will also result in a reduction in the Class IX supply workload. Since the Army supply system is demand based, the number of transactions and the storage workload will decrease in direct proportion to the RAM-driven decrease in aircraft failures. The reduction in supply workload translates one-to-one to the transportation system. If less parts are stocked and used, less transportation is required.

Comparison with Other LHX Maintenance Manpower Analyses

Other maintenance manpower analyses that have been conducted in support of a 2LM concept for the LHX include the COEA, and HARDMAN comparability analyses. This section contains a discussion of the differences between the methods used to estimate the maintenance manpower requirements for the LHX and where possible a comparison is made between the manpower estimates. In the case of the COEA, data were not available to the research team and therefore the comparison is limited to the method.

HARDMAN Comparison. The 2LM maintenance manpower estimates were developed for the AAD for direct maintainers with the total authorized direct MMH held constant at 1,241 and 1,423 annual hours for AVUM and AVIM maintainers, respectively. HARDMAN analyses were performed for all LHX aircraft in the AAD excluding the LHX aircraft in an AHB and Medevac Battalion. All analyses were performed using both DA and MAA flying hours.

Employing the DA wartime flying hour program of 848 annual flying hours, HARDMAN estimated a requirement of 1,361.9 MMH/day for the LHX employing a 2LM concept. This number is significantly less than the current manpower available in the AAD. It is an improvement of 61% over the current AAD maintenance capability. The HARDMAN estimate is 2% better than the estimate derived using the DA wartime flying hour program and maintenance ratio specified for the LHX under a 2LM structure in the LHX RAM Rationale Report (USAAVNC, 1985c). It should be noted that the HARDMAN estimate is for 189 LHX aircraft and all other manpower estimates are based upon 238 LHX aircraft in the AAD. The exclusion of an AHB and Medevac Battalion may account for the increased manpower savings as estimated by HARDMAN. All analyses assume a one for one replacement of LHX for AH-1, OH-58, and UH-1 aircraft.

Assuming a requirement of 2,094 annual flying hours, HARDMAN analyses estimate an LHX maintenance manpower requirement of 3,194.1 MMH/day. This estimate is a 10% savings over the current AAD capability. HARDMAN, therefore, indicates that given current RAM characteristics and the MAA flying hour program, the LHX can be maintained given current manpower authorizations.

Differences between the HARDMAN estimate and the estimate derived from the LHX RAM Rationale Report can be attributed partially to the fact that HARDMAN results are based upon the development of a baseline comparison system, (a hypothetical system representing elements of predecessor systems and, possibly the maintenance ratio) while the other effort derives manpower requirements solely from the LHX RAM goals. The two sources for baseline values would lead logically to some variance in estimate results.

COEA Comparison. The approach taken in the COEA to develop maintenance manpower requirements for the LHX under a 2LM structure is like the HARDMAN approach in that the process establishes manpower requirements through a historical approach. Although the COEA bases its maintenance manpower estimates on predecessor system data, the method is based on a "lessons learned" approach to the design of a conceptual system. The method identifies manpower problems in predecessor systems and an attempt is made to determine a solution and ensure that the problems are not repeated in the developing system.

The method identifies the relevant predecessor systems with their associated relevant maintenance MOS. Task lists are then

developed, predecessor data are collected, and a task analysis is conducted to identify those that are manpower resource intensive. The resource intensive tasks provide possible indications of problem areas in the developing system that may be limited or eliminated in the system design to help ensure system supportability. The difference between the approach taken in the COEA and the HARDMAN method is the emphasis on task performance instead of system component reliability.

In the case of the LHX, the COEA uses modified UH-60 MARC factor values to determine LHX maintenance manpower requirements. The COEA also employs a DA flying hour rate of 780 flying hours per year which is equivalent to the flying hour program for the AH-1. Other estimates use 848 DA flying hour requirements. HARDMAN uses 1,241 and 1,423 direct MMH authorized for CS and CSS activities respectively whereas, the COEA employs the requirement of 1,241 direct MMH per year for all division repairers without regard to whether they are considered CS or CSS activities. The differences in the factors described above used in various analyses limit the comparisons between the 2LM manpower requirements developed in the LHX HARDMAN Analyses and the LHX COEA Analyses.

Although COEA manpower estimates were not available, it is expected that they will differ from the HARDMAN and flying hour estimates due to the differences in assumptions and methods. However, it is anticipated that as the development process of the emerging system becomes more defined and specific system data become available, the different approaches will provide more nearly equivalent manpower estimates.

Summary of Findings

The primary finding of this effort is that maintenance personnel required for the LHX are available in the existing force structure given the current LHX RAM characteristics and system design characteristics. All methods of analysis investigated indicate that manpower savings over current authorizations are likely. However, it should be noted that these savings are based upon extremely diverse estimates of mission requirements and are contingent upon the system performing as designed to include the correct operation of BIT/BITE, ATE, extensive use of LRUs, and the compatibility of a 2LM structure with remaining support systems.

Given the current structure of the AAD, manpower spaces required are likely to be reduced for the LHX operating under a 2LM concept. The evaluation of which spaces should be eliminated or combined and the positioning of MOS must be done in consideration of the maintenance requirements of existing aircraft systems that are scheduled to remain in the division. Therefore an investigation of MOS consolidation should be done during Phase II of the USAALS 2LM investigation.

The reduction in direct maintenance manpower required for the LHX is the result of the RAM goals, LRU concept, and BIT/BITE. The only saving directly attributable to the 2LM concept will result from the elimination of overhead personnel associated with the existing third level of maintenance. Decisions on adjustments to the force structure cannot be made until the feasibility of maintaining the remainder of the existing fleet under a 2LM system is investigated.

The maintenance manpower requirements are sensitive to both the 2.6 MMH/FH goal and the number of direct MMH assumed to be available for each repairer. Differences among methods can be partially attributed to differences in assumptions used in the analyses regarding maintenance ratios and MMH available for repairers. The approaches taken in the different analyses also account for variations in the maintenance manpower required for the LHX under a 2LM structure.

The savings discussed above do not address or eliminate issues related to depot support in the event that in-theater on-aircraft depot support is required. The current concept tasks the depot to support the supply system and although it is unlikely that on-aircraft depot support will be completely eliminated, the current concept and goals reduce it to negligible proportions. A further discussion of on-aircraft depot support can be found in Frederickson, Lindquist and Lemen (1989).

Evaluation

The dual objectives of the LHX MANPRINT Research Program (R&D versus analytic support to the LHX community) provided the basis for a mixed evaluation of the 2LM research effort. Since data related to the implementation of the 2LM concept were unavailable, manpower implications could be examined only as possible outcomes rather than as concrete values. Also, the methods employed to calculate maintenance manpower requirements were sensitive primarily to RAM characteristics of the LHX and required flying hours, not structural changes in the maintenance organization. As such, the only impact of 2LM that can be presented with comfort in its validity and reliability is a reduction in manpower in overhead operations resulting from reduction in the organizational levels involved in the maintenance process.

Other serendipitous results were useful, however. For example, the comparisons between different predictions provided by this effort and the HARDMAN analyses were useful in explaining how different assumptions are responsible for different numbers. (Their relative value, use and accuracy will depend on application requirements.) Also, there were great overall benefits derived from the 2LM maintenance research effort in the lessons learned by the research team. The most important implications of the 2LM project are not found in the results provided by the analyses, but in the problems and qualifications

surrounding the results and in the advances made in how to approach MANPRINT questions.

An Analysis of Electronic Aids to Maintenance for the LHX

Introduction

A key assumption in the rationale underlying the movement toward a 2LM concept for the LHX is that the system will make extensive use of BIT/BITE. The BIT/BITE technology projected for the LHX is still under development and represents one example of a broader category of technologies classified as electronic aids to maintenance. For purposes of this report, EAM are defined as any instrument, device, component, or software which serves to provide information to operations or maintenance personnel regarding the status of a weapon system including information on system or subsystem failures that have occurred, are occurring, or may occur. The equipment and software may be an integral part of the weapon system or it may be in the form of instruments or other equipment that are electronically connected to the weapon system to perform the EAM function. Alternatively, the EAM may consist of instruments or testers located in a fixed facility and used to test portions of a weapon system, or even a whole system, which has been removed from its normal field operating environment.

In their most basic form, EAM have been used to support maintenance activities for a considerable period of time--since the earliest days of military electro-mechanical systems. In recent years, however, there has been a shift in the usage concept underlying these maintenance support tools. Initially, the EAM concept was one of using status monitoring and test equipment to support the maintenance repairer; the maintenance repairer remained the key element in the maintenance activity. In recent years, particularly with the increasing availability and application of microcomputer technology in the maintenance domain, the focus of the EAM usage concept has shifted from the man to the machine (i.e., a maintenance function re-allocation from man to machine). Complex EAM have been developed in which maintenance repairers can almost be thought of as being subordinate to the electronic aids. Using these systems, fault detection and isolation (the most complex aspects of maintenance) can be carried out, in theory at least, virtually without human intervention.

The objectives underlying the shift in focus from man to machine in an EAM intensive maintenance environment are threefold: (1) to increase operational availability (and thus combat readiness), (2) to save maintenance time, and (3) to reduce maintenance-related personnel costs. Both integral and external test equipment can help to ensure that a weapon system is functioning properly. In the event of a malfunction, it can provide information to the operator to cancel or abort a mission, or to compensate for the malfunction if the mission continues.

Information provided to maintenance personnel, regardless of levels, can enable faster repair or reduce the labor required to effect the repair. In some cases, where the weapon system is extremely complex, timely diagnosis may not be possible without EAM. Furthermore, in the case of highly automated EAM, human intervention may only be required for initial setup of the EAM. Once the initial setup has been accomplished, the test equipment performs the entire diagnosis. Shifting the focus of fault detection and isolation from humans to EAM theoretically has the effect of: (1) increasing maintenance efficiency (with a corresponding reduction in maintenance manpower requirements), (2) reducing personnel selection criteria (fault isolation is one of the most cognitively demanding aspects of a maintenance repairer's job), and (3) reducing maintenance training time and complexity (time devoted to training in diagnostics and fault isolation can be reduced significantly).

All of the features associated with extensive use of EAM are extremely appealing to system designers and procurement decision makers who must develop systems to operate in a resource constrained environment. However, the ability of EAM to provide the benefits described above for future weapon systems is related directly to the state-of-the-art of EAM technology and the performance of such systems in the field.

The EAM analysis grew out of a concern on the part of ARI that a major problem with respect to the operational availability (A_O) of the LHX and other future Army systems would involve the capabilities and performance of various EAM (e.g., BIT/BITE, ATE, prognostic systems, etc.). MTTRs for various weapon system components (a major factor in system availability planning) and the system's maintenance and logistics support MPT requirements are based upon projections concerning the performance of the various planned EAM systems. Hence, performance deficiencies on the part of the weapon system's EAM could have serious consequences with respect to both system availability and MPT requirements.

ARI's concern regarding the performance of EAM systems was based upon published reports, field observations, and anecdotal information indicating that the operational performance of EAM on current DoD systems often falls considerably short of developmental goals. The reported reasons for the operational inadequacies of EAM range from purely technical to human. Often, for example, automatic fault detection and isolation systems are not exhaustive in their coverage of system malfunctions, but the gaps are not discovered until after users have gained some experience with the system. In other situations, improperly trained or careless maintenance repairers are the reported cause of EAM performance inadequacies. Whatever the cause, operational inadequacies on the part of EAM can lead to a variety of undesirable consequences. These consequences can range from lowered rates of A_O (i.e., unit maintenance personnel can repair their equipment but not as quickly as planned) to a total

inability of unit maintenance personnel to maintain their equipment without significant outside assistance.

Systems designed to perform EAM functions may be classified into two basic categories: BIT/BITE and ATE. The first category, BIT/BITE, refers to equipment which is an integral part of the system or connected to the system and carried on-board when the system is operating. The second category, ATE, performs similar functions as BITE but is used during maintenance operations when the system is not involved in mission operations. The BIT function of EAM involves both hardware and software systems. BITE refers to the hardware portion of BIT and for the rest of EAM analysis discussion will be included in the term BIT.

Research Objectives

Given the serious implications of inadequate operational performance of EAM for future weapon systems, the EAM research effort was chartered with three principal objectives:

1. Identify failures or inadequacies for EAM used in recent DoD weapon systems.

2. Project the results of recent weapon systems EAM failures or inadequacies to estimate EAM performance for the LHX.

3. Identify and evaluate MPT-related solutions that can be used to aid LHX maintenance organizations in coping with EAM failures or inadequacies.

Research Overview

To achieve the objectives noted above, the research effort was conducted in two phases. The first of the two phases was a research effort to determine the state-of-the-art of EAM technology with a particular emphasis on BIT and DoD experience with BIT in existing systems. The second phase was focused on development of a prototype model which could be used to conduct analyses examining the implications of BIT performance for the LHX.

The first phase of the research effort consisted of a literature search and compilation of data on the performance of BIT in selected weapon systems in the military inventory. The literature search was used to compile a brief history of BIT, to identify the strengths and weaknesses of BIT, and to determine what might reasonably be expected of BIT as applied in the LHX. Data were compiled on existing systems to establish a base case from which LHX BIT performance could be developed.

The second phase of the effort consisted of modeling BIT performance in the LHX context with the outputs reflecting mission capability. Different levels of BIT performance were

analyzed to identify the sensitivity of mission capability to the various failure modes. Given the early stage of development of the LHX, precise data related to the LHX itself were unavailable. Likewise, the technology used in EAM for the LHX was still under development. For these reasons, the inferences made regarding EAM performance for the LHX were based on the integration of data from predecessor systems with the LHX concepts. Therefore, the results of the prototype modeling should be interpreted as the results of "first-cut" analyses and re-examined as new data, specific to the LHX, become available in the future.

After modeling LHX BIT performance, MPT solutions were investigated in terms of their ability to affect the more sensitive failure areas. A brief discussion of the model and the results of the analyses are provided below.

Phase I

The research conducted during the first phase of the EAM project can be divided into two tasks. The first task was a review of the literature to determine the state-of-the-art in EAM technology. Given the emphasis on BIT in the LHX program, particular attention was directed to the investigation of this form of EAM technology.

The second research task completed in Phase I was to review all available data on the performance of BIT in relevant DoD systems. This review included an examination of BIT performance in Navy and Air Force aircraft as well as a number of Army systems. The review of performance of BIT in Army systems included the collection of unpublished data on the OH-58D and AH-64 helicopters.

While the principal focus of the work in Phase I was to determine the projected performance of BIT based on DoD experience, the reader needs some familiarity with the state-of-the-art in BIT technology to provide an appropriate context in which to view the findings. For this reason, a synopsis of the findings from the review of BIT technology is presented below.

BIT is incorporated into prime equipment to perform two basic functions, fault detection and fault isolation. The fault detection function includes two tasks, system monitoring and system checkout. The fault isolation function represents a third, distinct task which involves the identification of the particular component or subsystem in which the failure has occurred. The ability of differing BIT designs to perform the three tasks varies with the characteristics of the equipment and criticality of the BIT function.

State-of-the-Art in BIT Technology

System Monitoring. The design of equipment, such as automated navigation systems, whose failure can affect the safety of flight has led to the development of BIT which interacts with, and controls, the operation of the system. Such equipment usually involves many electronic components which must "communicate" with one another. Data buses provide the communication links between different parts of the system in a similar manner to the way telephone lines provide communication links between telephones. During operation of systems which are interconnected by data buses, there is also a need to monitor equipment continuously on the bus to avoid using erroneous data. This has led to the development of software monitoring of peripheral equipment. When redundant systems are incorporated, it becomes necessary to monitor the active channel and, if inactive-standby redundancy is employed, to switch over to the second channel upon failure. Systems, such as warning receivers designed to alert the crew only when selected signals such as threat antiaircraft radar are received, require some form of periodic test to verify system integrity. Both modes of system monitoring, continuous and periodic, have become prime functions of BIT. In both cases the BIT automatically assesses the system. In theory at least, there are no demands put on the operator until the BIT has diagnosed a fault.

System Checkout. The second task of BIT is to accomplish system checkout prior to operation. During system checkout, the BIT, with possible crew intervention, performs functional checks to ensure that the system is fully operational. This type of check includes checks of the BIT itself.

Fault Isolation. A third and distinct task of BIT is to aid the maintenance crew in isolating faults to the failed subsystem, component, or LRU. This function of BIT is the most complicated and is the one which is the most important in terms of cost and manpower, personnel and training. To be effective, BIT must correctly detect a system malfunction, and then correctly isolate the cause to the failed component.

BIT Failure Modes

BIT failures fall into three basic categories each of which have the potential to interfere with or adversely affect the availability of the mission system. The categories and their effects are:

Induced failures. Induced failures are faults in the host or object system that are caused by a malfunction or failure of the BIT. That is, the BIT malfunctions in such a way that it causes damage to or interferes with the proper functioning of the host system. If the BIT is fully integrated with the host system and therefore shares circuitry, the opportunity for induced failures to occur increases. At the same time, integration makes

identification of cause and effect with respect to the BIT more difficult. Induced failures increase the not-available-time of the mission system because if the BIT did not exist, the failure and its associated not-mission-capable maintenance or supply status would not have occurred.

False indications. False indications are either an indication of a fault when none exists or the failure to indicate a fault when one does exist. The first problem, false indication of a fault, is identified by an inability to duplicate the fault during a retest. Therefore, they are often called "could not duplicate" (CND) faults. However, not all CND faults are false indications. CND faults are also caused by intermittent failures or a weakened condition. They are often warnings of a hard failure and if recognized as such, can greatly aid the maintenance process. Until a hard failure occurs, however, it is extremely difficult to isolate the problem.

Although a false indication of a fault does not actually change the condition of the mission system, the operator has no choice except to behave as if the report is true until further testing proves otherwise. Until such testing, which can range from a few seconds for a recycle of the BIT to several hours for complex off-system diagnostics, is completed, the system is not available.

In the second problem, false indication of a ready condition, the BIT does not indicate a failure when the system has a valid failure. Failure to report faults occurs most often in circuits which have multiple faults and not all of them are identified. The implications of a failure to report a faulty condition are that continued operation may cause a catastrophic failure causing the total loss of the system from the inventory, or that further damage may occur resulting in increased maintenance time or a mission failure due to the fact the fault is not discovered until an attempt is made to use the system. If the mission is time sensitive, it may not be possible to employ another mission system, whereas if the fault had been identified earlier by the BIT, planning changes may have avoided an actual mission failure.

Isolation error. Isolation error occurs when BIT detects a fault, but when operated in the maintenance troubleshooting mode, isolates the cause of the fault to the wrong component or LRU. Incorrect reporting of faults occurs during the fault isolation or diagnostic process. It happens most often in circuits that are spread over several circuit boards. BIT can easily identify failures and locate them to a general circuit, but has difficulty isolating the fault to an exact location. Consequently, the wrong circuit board is reported as faulty or the BIT is unable to complete the diagnostic. All of these instances cause downtime of the system and necessitate the presence of maintenance personnel. A false isolation impacts availability by directly increasing the maintenance time. First, the component which was

falsely identified as failed must be repaired or replaced. Subsequent to the repair, it will be noted that the original fault in the mission system still exists thus necessitating alternative troubleshooting procedures and repair of the component that has actually failed.

Automatic Test Equipment

In those cases where there is no BIT, or the BIT fails, the next diagnostic option is to use ATE. ATE is separate, external test equipment that contains circuitry very similar to BIT and which performs diagnosis of otherwise identified faults in much the same manner as BIT.

Test Sets

In the absence of both BIT and ATE, test sets are the next available diagnostic tool. Test sets are stand alone pieces of diagnostic equipment. They are used to diagnose limited components such as LRUs or shop replaceable units, or to diagnose limited functions such as the continuity of a line, an output voltage or a mechanical function such as rotor blade tracking.

Limitations Of Current EAM Technology And Systems

EAM technology has several important limitations related to the state-of-the-art of technology and to the nature of BIT itself. Today's equipment systems usually consist of several smaller subsystems, which are all somewhat unique. Due to the differences in these subsystems, the faults occurring within an overall system are not normally distributed. Typically, 20% of a system will be the source of 80% of the faults (Navy Personnel Research & Development Center [NPRDC], 1985). Efforts to develop on-board BIT for the entire system would be cost prohibitive, even if it were possible. The limitations include:

- On-line background operation,
- Limited hardware real estate (room on-board), software memory and computing time, and
- Isolation capabilities.

BIT operates on-line to detect failures and to monitor system status, and operates off-line to isolate failures. Operating on-line requires BIT to function in the background so it will not interfere with normal operation of the subsystem under test. In normal operation, or if BIT experiences a malfunction, its operation should not affect the system operation in any way. However, since the BIT must be connected directly to the circuitry of the host system, it is not possible to eliminate BIT induced malfunctions totally in the host system. The requirement to be non-interfering limits the types of tests that may be performed by BIT.

BIT is also limited in its isolation capabilities. Unless an interface is provided, mechanical systems cannot be accessed. As a simplistic example, consider the engine of an automobile. To monitor the temperature, a temperature sensor is placed in the engine and attached by a cable to a gauge that displays the current temperature of the engine. To monitor the air pressure in the tires is not so simple. For some subsystems, it is more practical to use some form of external test equipment, in this case a tire gauge. Electro-mechanical systems often have sensors providing information to BIT, on which BIT must rely. The maintainer will have to fault isolate those systems not tested by BIT using off-board ATE.

Circuits which are spread out over several circuit boards pose a difficult problem to BIT isolation. BIT can detect which circuit is faulty and even which area is faulty, but if that part of the circuit is located on several different circuit boards, BIT cannot determine which circuit board has the faulty component. This adds to the false isolation errors committed by BIT. To avoid this problem, circuits should be contained on as few circuit boards as possible.

ATE is not hampered by the same limitations as BIT. Although ATE is limited to a reasonable size, the entire equipment is dedicated to test and evaluation, eliminating the need to share computer time with the host system allowing it to perform more thorough tests.

The major limitation of ATE is the interface between it and the subsystem under test. In a typical set up, several test leads and test probes will be connected from the ATE to test points on the subsystem. These test points must be easily accessible to the ATE and also provide pertinent information about the subsystem under test. If provisions have not been made during the design of the subsystem for pertinent test points, the ATE may not be able to fault isolate the subsystem accurately.

Many of the limitations for both BIT and ATE can be avoided in the design of the overall system. Alternate methods of monitoring subsystems can be found for BIT to monitor adequately and fault detect on-line systems. Fault isolation can be accomplished for the system using both BIT and ATE. The maintainer will have to be involved for a small percentage of fault isolation, but this small percentage is typically the most difficult to isolate.

Future Directions of EAM Technology and Systems

There are several new areas of technology which will greatly affect EAM. These areas include artificial intelligence, prognostics, very high speed integrated circuits, and automated maintenance manuals.

Artificial Intelligence. Artificial intelligence (AI) technology is intended to design and produce "intelligent" computers that can imitate the human thought process, yet attain more accurate results. AI technology has grown significantly over the past several years. The growth has been primarily to extend the application of technology to commercial systems rather than develop new technology. The most significant efforts in AI have been in the area of expert systems and natural language understanding. (Daniels, 1986).

The goal in adapting expert systems to maintenance diagnostics is to provide an intelligent maintenance aid to enable the maintainer to reduce the fault isolation time, improve the accuracy of the diagnosis and respond rapidly to changing situations. Maintenance and fault diagnosis are very promising areas for expert systems.

For electronic fault diagnosis, the data base of the expert system should consist of two kinds of information: detailed specifications for the equipment to be diagnosed and results of measurements. The specifications consist of such information as functional descriptions, interconnections, nominal values for normal operating parameters and component values, and tolerances. These kinds of information must be available for each piece of equipment and are equivalent to the manuals and performance specifications maintenance personnel would use. The additional information in the knowledge base consists of symptoms data, results of measurements, general diagnostic methods, rules associated with particular classes of equipment, and rules peculiar to the specific equipment being tested.

In operation, the diagnostic expert system examines the knowledge base, looking for rules to apply. In the early stages of diagnosis, the application of rules is primarily for the purpose of making key measurements to be added to the data base. In later steps, many inferences are possible with only limited additional measurements. One objective of using expert systems for diagnosis is to minimize the total testing time by reducing the number of measurements necessary to diagnose the fault. At each step, the expert system looks for a final diagnosis, and where that is not possible with the data available, it determines the next best test to make in order to rule out the most possibilities.

The application of AI to maintenance and fault diagnosis will improve upon the inroads BIT made. The AI maintenance system will be more accurate, more thorough, faster, and will be able to test more functions. The amount of manual fault diagnostics will decrease; however, the human maintainer will still be required to override the EAM system if need be and to operate the on demand fault diagnostics. (Papenhausen, 1986).

Prognostics. Prognostics attempt to predict impending failures or malfunctions. This technology is receiving increased

attention and is growing rapidly. Performing prognostics requires BIT with a reasonable amount of data recording and processing capability. Prognostics is accomplished as follows: The functioning of a particular unit, such as a sensor or a circuit, is frequently monitored and the observations recorded. As the unit ages, its performance tends to drift away from its design performance. The resulting performance may still be within allowable tolerances. By monitoring these changes, they can be used to predict the occurrence of continual and larger changes leading to a failure or malfunction. The EAM would then warn the operators or maintainers of incipient failures.

Prognostics would allow a higher potential mission effectiveness, with the ability to abort or compensate when a failure is about to occur. It would also help eliminate periodic maintenance that is used to check for the sort of impending failure that the prognostic monitoring is performing. Prognostics is an aid to the maintainer, allowing him to perform maintenance on an "as needed" basis. It also enables him to perform maintenance on equipment which is about to fail without having to wait until a mission is affected. The maintainers' tasks will not be eliminated, just made more efficient.

Very High Speed Integrated Circuit (VHSIC). VHSIC technology incorporates advanced etching techniques to put more gates on a single chip than ever before. This allows several functions to be placed on a single chip reducing the paths between gates and the power required to drive the signals. Both bipolar and complimentary metal oxide semi-conductor technology are used providing a faster circuit with less power consumption.

VHSIC technology provides faster operating circuits which, when used in digital computers, allows greater computing capability. It also provides significant potential benefits for BIT. Increased speeds for weapon system on-board processors can permit their use for both the weapon data processing and control, and also for BIT processing. BIT can be performed at greater speeds without the need for significant additional equipment, and the associated cost and space. VHSIC will aid the other technological advances but will not have any direct impact on human maintenance functions.

Several companies, including TRW Electronics Systems Group, have developed chip sets which utilize VHSIC technology. These chips can handle a wide variety of high speed sorting, arithmetic, memory, and interconnect functions. VHSIC technology will soon be available for use in production enabling systems designers to incorporate it into EAM.

Automated Maintenance Manuals. Automating a maintenance manual simply means putting the information on a medium which is easily accessed by a computer. The manual can be on a hard disk, a floppy disk or a WORM (write once read mostly) disk. The computer is used to display the appropriate information

automatically. It encourages interactive diagnostics with the maintenance personnel increasing the speed and success of repair.

The user is prompted to call up the appropriate manual by the fault detection and location computer. He may then follow the instructions prompted by the maintenance manual. For example, many manuals utilize fault trees to aid the maintainer in debugging the equipment. The same process would occur here except the branching is performed by the computer eliminating errors due to the maintainer accidently branching to the wrong page in the manual. The user is queried and the computer either asks another question or it branches to a new page. The entire process is similar to using a programmed textbook.

The maintainer may also use the maintenance manual as a reference. He would bring the maintenance manual up as before but instead of allowing the computer to step him through the maintenance procedures he would search for the specific item he needs. The search is performed by the computer given a keyword, the name of an equipment item, a task, etc. The search process is performed much like it is on a word processor. If the maintainer is unsure of exactly what he needs, he may scan through the manual a page at a time, a chapter at a time or by any other method he wishes. The automated maintenance manual provides fast access to information and easy cross-referencing.

Summary of EAM Technology

The application of evolving technologies such as AI and prognostics provide significant opportunities for EAM to enhance future weapon system availability through (1) rapid accurate fault detection, (2) rapid fault isolation, (3) predicting impending failures, and (4) providing quick access to technical information. Judiciously applied, all of the above can enable personnel reductions in terms of both numbers and aptitudes required. However, size, weight, cost, and the need not to interfere with normal system operation act as limiting factors to the practical application of BIT. On the other hand, those limitations are mitigated somewhat by the fact that the preponderance of system failures occur in a relatively small percentage of the weapon system.

The next section of the report provides a discussion of the research conducted to examine the experiences to date of the military services with EAM and more specifically military experience with BIT. The discussion represents a brief summary of the findings. A more detailed review of this research is available in a separate research report on the EAM research effort (Frederickson et al., 1989).

DoD Experience with BIT Technology

The research conducted to examine the DoD experience with BIT technology involved two forms of data collection. The first

source of information was published and unpublished investigations describing the performance of EAM or BIT in DoD systems. The literature search included a review of professional journals, technical reports, research reports, and other DoD publications such as the final reports from DoD or Armed Services scientific advisory committees. The first stage in identification of relevant sources of information was achieved through traditional literature search methods such as use of the Defense Technical Information Center. Based on previous experience in evaluation of system performance, the research team suspected that additional unpublished studies could be obtained through direct contact with relevant agencies and organizations within DoD. Thus, a second stage in identifying literature was accomplished through a series of phone calls and visits to agencies within the Army, Navy, and Air Force. This second stage of the literature search produced a number of reports which were not yet available in a published form. In addition to summative reports describing the general performance of BIT across various systems, the two stages of the literature review produced reports describing the performance of BIT in the following systems:

- Navy

    S-3A (aircraft)

    C-5A (aircraft)

    F-18 Radar system

    Aegis

- Air Force

    F-15 (aircraft)

    F-16A (aircraft)

- Army

    M-1 Tank

    Multiple Launch Rocket System

A second source of information regarding DoD experience with EAM was the results of new analyses conducted in this effort. The research team acquired and analyzed new data related to the performance of EAM in three Army systems: the OH-58D helicopter, the AH-64 helicopter, and the Patriot Missile System. The data on the performance of EAM in the three Army systems were obtained from RAM records.

Literature Search

Information on the specific performance of BIT technology in each of the Navy, Air Force, and Army systems analyzed in previous efforts is included in Frederickson et al. (1989). For purposes of this report, a review of the general trends identified in the published and unpublished reports seems most appropriate. The experience of the Navy, Air Force, and Army have been fairly similar. Although BIT has made a major contribution to controlling weapon system maintenance time and maintenance training, it has not been an unqualified success.

A Defense Science Board panel found that most attempts to deal with increasingly complex weapon systems and decreasing maintenance manpower through the use of high performance technical systems have produced several kinds of problems: "shortages of skilled personnel and spare parts, unnecessary maintenance, incompatible test equipment and inflexible maintenance practices" (Defense Science Board [DSB], 1982). They attribute many of the difficulties to the removal-and-replace philosophy, "which depends heavily on built-in diagnostic and automatic check-out equipment." (DSB, 1982). In using high-tech concepts to reduce the complexity of the operator tasks, "the complexity of maintenance tasks has shot up" (DSB, 1982). The essence of the findings of the Defense Science Board was that the LRU concept combined with the use of BIT fault detection/isolation has not worked as desired. The Defense Science Board's panel concluded:

> "Concerns relative to the maintainability of equipment with a multiplicity of removable assemblies were quieted with the promise of automatic fault detection and isolation capabilities that stretched into the high ninety percentile range. While these promises looked good on paper and were incorporated in almost all specifications, the actual field performance has been nothing short of a disaster" (DSB, 1982).

Two new maintenance problems have come about as a result of the use of automatic fault detection and isolation equipment and the relatively poor performance of such equipment. First, the diagnostic equipment in many cases has turned out to be as complicated to operate and maintain as the prime system equipment itself. For example, Spinney (1981) has reported that the automatic test station used with the Air Force's F-15 aircraft contains 220,000 parts that have to be fault isolated and replaced when they fail. That is more than twice the number of electronic parts in the F-15. There are over 280 different technical orders and 100 different computer programs on 530 reels of tape for use in troubleshooting the avionics subsystems. The hookup of the station requires up to 85 interface connections.

The second new maintenance problem is one created by the failure of the automated diagnostic equipment to detect and to

isolate faults correctly (high false alarm rates have been found to be the norm). When the automatic diagnostics do not work, manual techniques must be used, "which in turn requires that the repairer know how the system is integrated, what functions are performed in what boxes and how a failure in a particular box affects the system." (Carpenter-Huffman & Rostker, 1976).

Conclusions

The review of projects conducted to examine BIT performance in Navy, Air Force, and Army weapon systems resulted in the following conclusions:

- BIT has not proved to be as reliable as the designers would like it to be and thus fault detection and isolation cannot be totally automated.
- Repairers must be able to take over the troubleshooting tasks when BIT fails.
- BIT false alarm detection and erroneous isolation rates will have to be tolerated.
- Maintenance training may have to be up-graded to include system and subsystem function integration concepts in order to effect timely repairs when the BIT fails.
- The inclusion of BIT in major weapon systems has not resulted in significant maintenance manpower savings as originally predicted by system designers

While the performance of BIT technology has varied considerably from one system to another, reservations have been expressed concerning the ultimate gains to be achieved in even the most successful applications. For example, the operational readiness test system (ORTS) in the Aegis system has avoided many of the pitfalls found in other applications of BIT and ATE and is functioning as planned, thus enabling attainment of the desired mission capability. The success has been attributed to several factors, including "program management's emphasis on availability, no cutting corners on maintainability, and a long maturation program prior to Fleet introduction" (Nauta, 1985). Another factor that supported the success of the implementation was the use of technicians selected and trained under special procedures. However, "maintenance supervisors, while satisfied with ORTS capabilities, articulated their concern about what will happen to AEGIS once it is manned through the standard Navy personnel and training system" (Nauta, 1985).

It was not within the scope of this effort to identify specific EAM potentials under varying operational and climatic conditions. However, after completing the review of available reports on DoD experience with EAM, the research team concluded

that 90 to 95% coverage of electronic systems to the LRU level with a 95% reliability is approaching the limit of reasonable expectations. For other than electronic systems, the technological limit appears to be considerably lower.

More important than the technological limit is the understanding that the practical boundary for maintenance of any system is established by the interaction of hardware, maintenance personnel, maintenance concepts, and doctrine. Both the Navy and Air Force have most recently focused their attention on the development of integrated maintenance programs which simultaneously consider both advanced technology and the manpower in the design of maintenance systems. The Navy's Integrated Diagnostic Support System (NPRDC, 1985) and the Air Force's Generic Integrated Maintenance Diagnostics (Smith, 1986) both recognize the limits which can be achieved from a totally automated diagnostic technology. Both of these programs are designed to implement a balanced approach to integrating BIT or ATE technology with projected capabilities of the maintenance manpower pool.

New Analyses of Army BIT Performance Data

The sections below describe the data and results of the analyses conducted for the OH-58D, Patriot, and AH-64 systems. Specific data are reported for each of these systems because they are the most relevant data used in the prototype modeling for the LHX. The results of the analyses are not available in previously published reports.

OH-58D Helicopter. Although the OH-58 helicopter has been in the Army inventory for 20 years, the D model, which incorporates extensive EAM technology, underwent developmental testing at Yuma, Arizona. The OH-58D developmental effort offers an example of the difficulty of attempting to integrate BIT into existing subsystems that are being up-graded with state-of-the-art technology.

The RAM data (USAAVSCOM, 1986d) available on the BIT/BITE systems were based on contractor performed maintenance during the period July 7, 1984 to August 30, 1984. During that 52 day period, 98 faults were detected over 305.6 flight hours. Table 7 presents a breakdown of the BIT performance.

Several questions are raised by this data. First, it is curious that the BIT systems were not used to their full capabilities for fault detection and isolation. The automatic testing was only used 54% of the time for detection and 2% of the time for isolation. The answer to the lack of use probably is due to the poor performance of BIT. BIT attempted to detect 53 times and failed 29 times. It failed to detect 11 faults. The other 18 missed detections were due to faulty BIT systems. With this kind of performance, repairers would quickly learn not to rely on the automatic testing for fault detection.

Table 7

OH-58D BIT Performance Analysis

Total faults detected	98	
BIT monitored	98/98	100%
BIT used for fault detection	53/98	54%
BIT used for isolation	2/98	2%
BIT detections when used	24/53	45%
BIT failed to detect	11/53	21%
BIT system found to be faulty	18/53	34%
BIT detections not duplicated/confirmed	41/98	42%
Total faults confirmed	47/98	48%
Successful BIT isolations when used	0/2	0%
BIT failed to isolate when used	2/2	100%
Resulting manual detections	74/98	76%
Manual isolations replacing BIT	45/47	96%

The lack of confidence in BIT evidently spread to its use for fault isolation. The automatic testing was used in only 2 of the 47 isolation attempts and it failed to isolate the fault both times. The non-use of BIT, however, may have been due to the fact that contractor personnel performed all corrective maintenance on the system. From their experience with the development of the system, the contractor maintenance personnel may have been so familiar with the faults that were detected that they immediately assumed the fault to be caused by certain low reliability components, and, thus, did not need to use BIT for isolation. However, only 45 of the causes of the 98 detected faults were isolated. So, the combined automatic and manual troubleshooting approach still was not used effectively.

The OH-58D data may be viewed as confirming the findings from the Air Force and the Army's Patriot programs which suggest the need for a long integrated development period for both weapon system and BIT. The technological up-grading process to include modern BIT systems in weapon system modernization evidently has not been worked out to eliminate significant reliability problems.

Patriot Missile System. The Patriot high altitude air defense guided missile system maintenance philosophy is to make the firing unit self-sufficient by providing repair at the operating site and to reduce maintenance requirements at the battery. No direct support maintenance is provided for system peculiar equipment. System peculiar maintenance support is provided by an Intermediate Maintenance Team and by the prime

contractor on an as-required basis. To meet the maintenance requirements, the Patriot ground support equipment is based on an extensive use of BIT for detecting and localizing system faults to LRUs. Defective LRUs are replaced and evacuated to higher maintenance echelons for repair (if they are, indeed, faulty).

To support the Patriot maintenance concept, a comprehensive Maintainability Program was initiated at the beginning of the Patriot Engineering Development Program in the early 1970s. The purpose of this program was to assure that "ease of maintenance features were incorporated into system design." The maintenance concept encompasses automatic and manual fault detection and isolation procedures. A full assessment of the maintenance concept has not been possible to date, due to the high reliability of the system itself, but some data are available. Over a period from September 1984 through November 1985, RAM data on Patriot systems in Germany, at White Sands Missile Range and at Fort Bliss owned by the Army revealed a false alarm detection rate of 13% (142 out of 1121). The MTTR during Follow On Evaluation III was 3.8 hours, compared to the goal of 2.0 hours. In 1982, a Maintenance Improvement Program was initiated following a reassessment of the maintenance concept, which concluded that a complex electronic system like the Patriot requires a backup level of maintenance between the field unit and the depot or factory. To compensate for the limitations of automatic diagnostics, a forward support element (the Patriot Field Army Support Center), made up of a team of highly skilled technicians (one warrant officer and nine E-7s), was created to provide on-site assistance to organizational maintenance personnel who have lower skill levels and less experience (Nauta, 1983).

AH-64 Helicopter. The AH-64 Apache Helicopter is the Army's first helicopter with extensive BIT incorporated in the design. Because of the similarity to LHX technology and operational environment, the AH-64 was selected as the base case from which to extrapolate LHX performance projections.

The BIT system in the AH-64 is called the Fault Detection/ Location System (FD/LS). The initial requirements that were established for FD/LS were:

- Provide on-board go or no-go status of mission and flight critical subsystems.
- Provide on-board isolation of electrical or electronic AVUM replaceable units (RU).
- Provide for crew monitoring of drive system.
- Provide 95% on-ground fault isolation.
- Provide no more than 2% erroneous fault detections.

- Provide 75% aircraft availability.

- Attain 0.9 hours mean time to repair.

- Achieve goal of 9.0 or less maintenance man-hours per flight hour.

These requirements were to be met through a maintenance concept which includes: BIT, diagnostic software, ground test equipment, ATE, technical manuals, and standard diagnostic procedures and equipment. The FD/LSs were to be designed so as not to degrade the performance of the system components being monitored. The on-board subsystems containing mission essential and flight critical AVUM RU are presented in Table 8.

Table 8

On-Board Subsystems Monitored by FD/LS

SUBSYSTEM	MISSION ESSENTIAL	FLIGHT CRITICAL
Environmental Control/Anti-ice	X	X
Navigation/Communications	X	
Fire Control	X	
FD/LS (Caution and Warnings)	X	X
Target Acquisition Designation Sight	X	
Pilot Night Vision Sensor	X	
Integrated Helmet and Display Sights System	X	
Flight Controls	X	X
Armament	X	
Multiplex	X	
Drive Controls	X	X

The on-board FD/LS consists of a number of detection and isolation methods for monitoring the mission essential and flight critical subsystems made up of 150 components. The fault detection/isolation modes that are used include automatic, semiautomatic actions, and manual. The automatic mode provides warning and status input to cockpit displays. The semiautomatic mode uses diagnostic items such as caution or warning panels, push-go-test buttons and computer prompt responses. The manual mode covers every maintenance action and procedure not using the FD/LS. The manual mode relies strictly on human observation. For the purposes of assessing the reliability of BIT systems, the RAM data were separated into two categories, automatic or semiautomatic, and manual.

AH-64 RAM data used in this project were collected on 1 RAM demonstrator (McDonnell Douglas Helicopter Company, 1986) and 4 trainer aircraft (USAAVSCOM, 1986b) at Fort Rucker, Alabama, from September through November 1985. The flight hours accumulated on these aircraft during this period was 1,290 hours. The second set of data was collected on 19 operational aircraft at Fort Hood, Texas, from April through July, 1986 (USAAVSCOM, 1986a). Over 1,000 flight hours were accumulated on the 19 aircraft during this period.

Two kinds of data were extracted from the RAM data printouts furnished by USAAVSCOM: FD/LS fault detection and isolation performance data; and, direct mean maintenance man-hours (MMMH) per repair when FD/LS failed. Both data were used in the extrapolation of the AH-64 BIT performance to assess the impact that the same kinds of performance might have on the LHX system. The FD/LS performance data are presented in Table 9. The data from the two samples are quite similar in nature. One significant difference was in the increased use of the FD/LS to detect and isolate system faults. FD/LS use for detection improved from 73% in the Fort Rucker sample to 96% in the Fort Hood sample. The improvement in FD/LS use for isolation was almost exactly the same percentage change, from 66% at Fort Rucker to 81% at Fort Hood. One problem area, BIT detections not duplicated/confirmed, increased from 32% at Fort Rucker to 39% at Fort Hood. False detections have a critical impact on the maintenance program in that they waste time and could lead to inappropriate maintenance actions which would further delay the repair of the system.

Another area where there was a slight decrease is FD/LS fault isolation performance. Successful FD/LS isolations dropped from 91% at Fort Rucker to 87% at Fort Hood. There are two components of the unsuccessful isolations: a pure failure to isolate the fault and isolation to the wrong component. The failure to isolate (6% at Fort Rucker versus 9% at Fort Hood) requires that fault isolation be carried out manually. This may place a skill burden on the maintenance repairer beyond his capabilities. This is one problem the Navy has found with which it must deal (Smith, 1986). It can be resolved by either upgrading the training program to provide such skills, or the aircraft (or subsystem thereof) can be evacuated to a maintenance echelon where repairers have the skills to cope with the problem.

Isolation to the wrong component creates several problems. This error first leads to a delay in repair when the identified AVUM RU is replaced and the detected fault is not corrected. Then either manual isolation procedures must be used or the aircraft (or subsystem) must be evacuated to depot. Therefore, both kinds of failure-to-isolate problems eventually have the same negative impact on the maintenance program. Data from Table 9 were used as input to HTI's ALDT model to project the impact that BIT performance similar to the AH-64 data would have on the LHX operational performance.

Table 9

AH-64A BIT Performance Analysis

	AH-64A* FT Rucker		AH-64A** FT Hood	
Total faults detected	126		251	
BIT monitored	101/126	80%	251/251	100%
BIT used to detect	74/101	73%	240/251	96%
BIT detections when used	70/74	95%	230/240	96%
BIT failed to detect	4/74	5%	10/240	4%
BIT system faulty			15/230	7%
BIT detections not duplicated/ confirmed	104/330	32%	90/230	39%
BIT not designed for isolation			167/240	70%
Detections designed for BIT isolation	101/101	100%	84/84	100%
BIT used to isolate	67/101	66%	68/84	81%
Successful BIT isolations when used	61/67	91%	59/68	87%
BIT failed to isolate when used	4/67	6%	6/6	89%
BIT failed to correctly isolate	2/67	3%	3/68	4%
Resulting manual detections	56/126	44%	21/251	8%
Manual isolations replacing BIT	40/101	40%	25/84	30%

*Fort Rucker data are from September - November 1985 RAM scoring period on one RAM demonstrator and four trainer aircraft.

**Fort Hood data are from 19 operational aircraft collected from April - July 1986.

Time To Repair Data

The Fort Hood AH-64 effort also produced some interesting data for the time it took to repair a fault. The direct MMMH for repairing faults when strictly manual detection, isolation, and repair procedures were used was 1.43. When BIT detected, but not designed for isolation, direct MMMH was 2.37. In those cases when BIT was designed to detect and isolate but failed to do one or both, MMMH increased to 3.15. The systematic increase from the pure manual procedures for completing manual maintenance tasks to the use of manual procedures to overcome BIT failures might reflect an increased complexity of equipment subsystems BIT was designed to cover, or it might reflect the skill level required to troubleshoot and repair those subsystems.

Summary of the Army Experience

Analysis of published investigations and examination of new data obtained during this research effort indicated that the Army has experienced similar difficulties with each of its previous BIT efforts. The BIT has not met performance expectations and BIT failures have equated to increased down time or increased and more complex maintenance. Furthermore, based on the rate of false alarm detections for the four most recent weapon systems (see Table 10), there has not been a significant improvement in BIT performance. The Patriot system has a much lower false alarm rate, but 13% is too high to meet all LHX RAM goals.

Table 10

False Alarm Detections (FADS)

SYSTEM	FADS/TOTAL	%
AH-64A FT Rucker (5 A/C)	104/330	32%
AH-64A FT Hood (19 A/C)	90/230	39%
OH-58D	41/98	42%
Patriot	142/1121	13%

Based on historical trends and new data analyzed in this effort, the research team concluded that it was unlikely that the goals established for BIT in the LHX would be obtained during initial fielding of the system. However, the data available do not provide adequate information to allow an accurate prediction of the actual level of reliability and accuracy which might be achieved with BIT technology available when the LHX is developed. For this reason, the focus of the second phase of the EAM research project was directed toward development of a model to examine the impact of various degrees and types of LHX BIT failure. The next section of the report provides an overview of this aspect of the research effort.

Phase II

Two of the principal objectives of this research effort were to assess the impact of projected BIT performance on LHX mission capability and to examine potential MPT solutions to compensate for maintenance problems created by failure of BIT to perform as expected. To achieve these objectives, it was necessary to develop a method for assessing the impact of BIT failure on the LHX. The research team used information from the LHX RAM Rationale Report (USAAVNC, 1985c) and data on BIT performance in the AH-64 to develop a computer model to conduct the required

analyses. The paragraphs below describe the research method and summarize the results obtained from the computer model. The description of this phase of the research effort begins with a brief overview of the design goals for BIT for the LHX.

LHX Design Goals

The design goals established for the LHX BIT are extremely broad and depend on successful development and implementation of new technology. The BIT is to apply to both electronic and mechanical components and, as such, must be capable of detecting and isolating faults to the LRU without the use of off-aircraft ATE with an accuracy of 98% for 100% of the electronic components and 75% of all other failure modes (USAAVSCOM, 1986c). Additionally, the BIT is to interface automatically with other automated aviation maintenance and maintenance management systems such as the predictive aircraft maintenance system and the automated log book (USAAVSCOM, 1986c).

Risk

Accurate and effective BIT performance would enable substantial savings in (1) maintenance manpower, (2) training time for maintenance personnel, (3) special tools and test equipment, and (4) repair parts storage and handling. In addition, the success of the BIT is critical to the LRU concept and the 2LM concept and impacts heavily on MOS consolidation plans and possibilities. Those benefits are predicated on the assumed time savings, simplification of maintenance tasks, and high level of accuracy of prognostication and diagnosis. Over-estimating BIT capability will put those same goals at serious risk. Specifically, as BIT performance varies from planned performance, maintenance and logistics delay times will increase.

Under the proposed 2LM concept, the failure to detect or isolate a fault correctly will require depot level intervention. This occurs because the user level is precluded from having off-aircraft ATE and because user personnel are not to be trained in piece part repair or the associated diagnostics. There is a finite amount of "not available time" associated with calling for maintenance assistance and with performing manual fault isolation.

Erroneous indications of faults and failure to isolate or isolation of a fault to the wrong LRU will also require depot intervention. In addition, false indications lead to an increase in the supply burden and in the component repair burden. Depot assistance will be necessary because user maintenance personnel do not have the wherewithal to confirm or deny a maintenance condition without BIT. The supply and component repair burdens will increase because a part will be used when none is required and the component repair activity will have to go through a diagnostic operation on the removed LRU only to prove that it is serviceable.

If the BIT does not create the anticipated work simplification by eliminating manual fault diagnosis and piece part repair below the depot level, the new groupings of tasks under existing or new MOS for the 2LM concept are at severe risk of being out of balance. The potential also exists to eliminate tasks based on predicted highly reliable BIT that still will be required when BIT performance is sub-par.

Projected Performance

The expectations for the BIT are quite high. In addition, a large portion of the logistics support programmed for the LHX assumes that the BIT will be a total success. The MTTR and delay times projected for the LHX are specific examples of goals affected by BIT performance. The feasibility of the MTTR goal of 0.5 hours is only possible if the BIT virtually eliminates diagnostic time and the LRU concept is successful. The BIT is critical to the LRU maintenance concept. The expected value of delay time incurred once a failure has occurred (5.5 hours) cannot be achieved if false BIT readings cause additional (and possibly unnecessary) delays awaiting parts, delays awaiting transportation to higher level maintenance, or delays awaiting higher level repairers.

Based on the findings from the research conducted in Phase I, there is good reason to believe that the BIT will not meet current performance expectations. Although conceptually possible, the overwhelming evidence is that the state-of-the-art of BIT technology is not sufficiently mature to achieve total success with the hardware. Unfortunately the scope of this contract combined with the closely held and proprietary nature of much of the technical data specific to the LHX BIT make it unrealistic to pinpoint exactly how effective the BIT will be. Instead, the research team examined the sensitivity of aircraft availability and maintenance manpower to BIT performance.

Method

The method employed in this research effort was to: (1) integrate the possible BIT failures into the ALDT model as published in the LHX RAM Rationale Report (USAAVNC, 1985c); (2) input the AH-64 BIT failure data into the model as the base case; (3) determine the sensitivity of mission capability to changes in BIT performance by improving the values for BIT performance incrementally and re-running the model; and (4) subjectively evaluate manpower, personnel, and training solutions as to their ability to affect the failure modes to which mission capability is most sensitive.

Integrating EAM Failures into ALDT Model

To assess the impact of various levels of BIT performance on aircraft availability, maintenance manpower, and logistics support concepts, it was necessary to determine the type of BIT failures that are likely and insert them into the ALDT model at each point at which they may occur. Figure 15 illustrates the types of BIT failures and where they may occur in the maintenance sequence.

False Indication. Under the heading of "false indication," there are two possibilities: (1) the BIT can fail to detect a fault, and (2) the BIT can indicate a fault when in actuality there is none. Either of those errors can occur during normal operation and thus obscure the fault until an attempt is made to operate the affected subsystem or instigate an otherwise unnecessary maintenance action. It is also possible for the BIT failure to occur during an after-maintenance check, again, either obscuring a fault or instigating a maintenance action. If the BIT failure occurs during normal operation, obscuring a fault can have serious mission and or safety implications. BIT failure during an after-maintenance check which instigates an unnecessary maintenance action adversely affects aircraft availability as well as wasting scarce maintenance resources. In both cases, current LHX maintenance concepts will require depot level maintenance intervention.

Isolation Error. There are two basic failure possibilities during fault isolation: (1) the BIT cannot locate the failed LRU, and (2) the BIT isolates improperly (attributes the fault to the wrong LRU). Unlike detection failures, isolation failures can occur only during maintenance. The impact, however, is very much the same. Erroneous fault isolation causes unnecessary down time, wastes maintenance manpower, and increases the consumption of LRUs.

Depot maintenance is required to both repair the BIT (assuming a hardware failure) and to isolate the fault of the original maintenance problem correctly.

Assessing the Impact of Degraded BIT Performance

The approach to investigating the impact of BIT performance on LHX maintenance began with the integration of possible BIT errors into the ALDT model published in the LHX RAM Rationale Report. Once integrated, the expected values for the delay time and repair time were computed for each of the possible paths in the model. Armed with those numbers, it is a relatively straight forward task to determine the expected availability and maintenance manpower requirement.

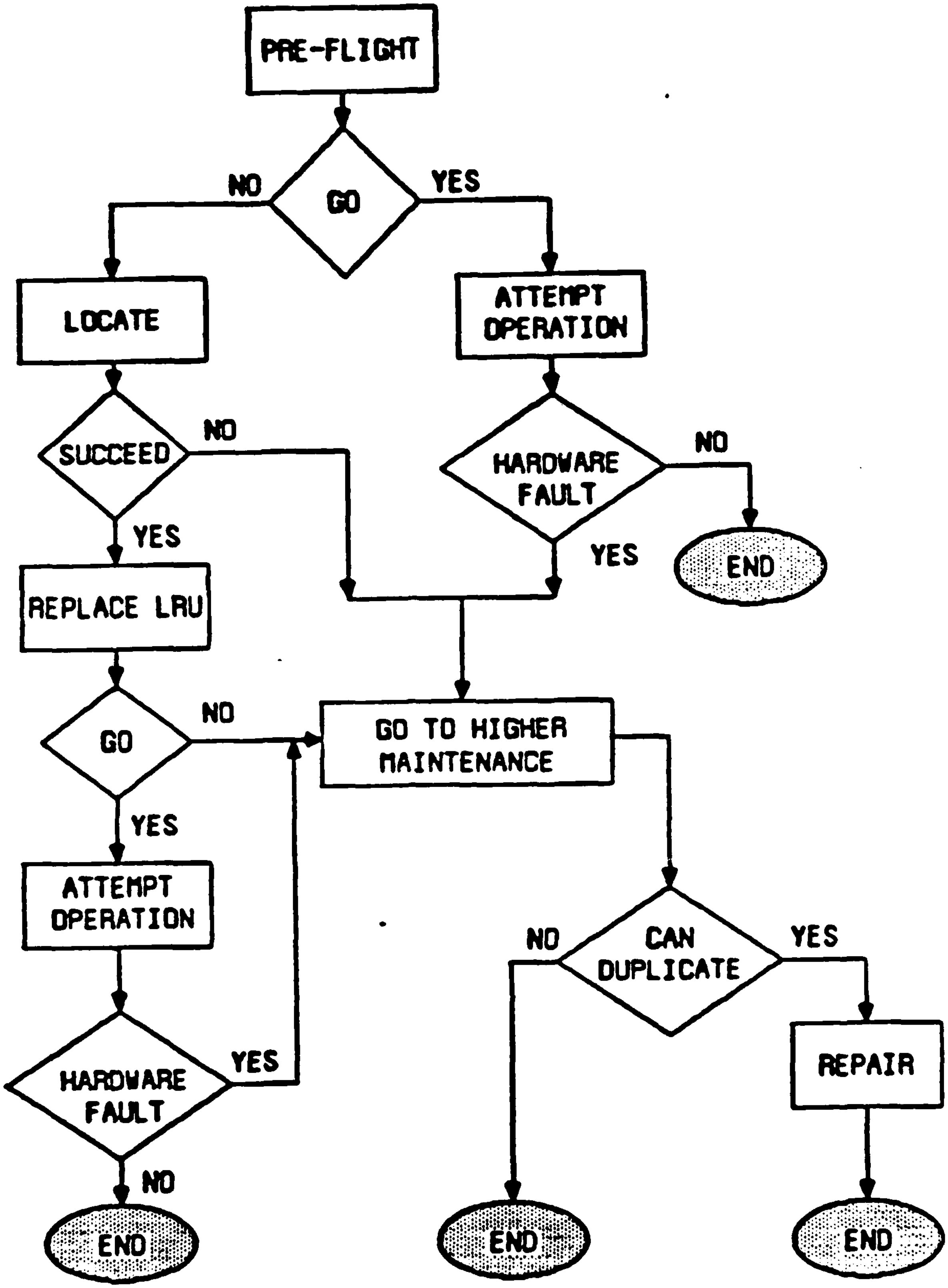

Figure 15. Types of BIT failures.

Figure 16 is the ALDT model as presented in the LHX RAM Rationale Report (USAAVNC, 1985c), and Figure 17 depicts the addition of the BIT failure possibilities, bad fault detection, or bad fault isolation.

Prior to adjusting the ALDT model to accommodate the BIT failure possibilities, the repair cycle in the model was not complete. Therefore, in every instance where the aircraft had been removed from the flight line, an operation was created to return it to the flight line upon completion of the maintenance action. In addition, an operation was added to repair the aircraft if it was not flight line repairable and did not need a part. The added operations are highlighted in Figure 17 by crosshatching.

The shaded decision points of Figure 17 are those that pertain exclusively to BIT. The logic is that there are only four possible ways for the BIT to perform:

(1) It can avoid performing at all because it was not designed to fault isolate a component. On the model this possibility is labeled "BIT APPLIES." This question is pertinent upon discovery of an aircraft condition requiring maintenance (an EMA) and at the beginning of checkout after maintenance has been performed.

(2) The second question is, "If the 'BIT APPLIES,' can it successfully isolate the fault to an LRU?" On the model, this is labeled "BIT CAN LOCATE FAULT." This question is pertinent only during the initial attempt at fault isolation. If the BIT cannot isolate the fault, it is necessary to exit to higher level maintenance since the user does not have off-aircraft diagnostic capability.

(3) The third question is, "If a repair action is complete and the 'BIT APPLIES,' upon initiating a checkout sequence does the BIT indicate that the original fault has been corrected?" This is labeled on the model as "BIT INDICATES GO." A negative response to this question contains the possibility that (a) the fault has been corrected but the BIT has failed and is giving a false indication, and (b) the BIT had failed during the earlier isolation sequence and isolated the cause of the EAM failure to the wrong LRU. Therefore, the probability of a "no response" is equal to the probability of isolation error plus the probability of a false indication. In either case, the only remedy is to go to higher maintenance.

(4) The last question is, "If a repair has been accomplished, and the 'BIT APPLIES,' and the 'BIT INDICATES GO,' does the aircraft system function properly?" This is labeled "HARDWARE OK" on the model. A negative response is indicative of the possibility that the BIT failed to detect a fault during the maintenance verification sequence. The model does not attempt to attribute that fault to faulty diagnosis, faulty replacement

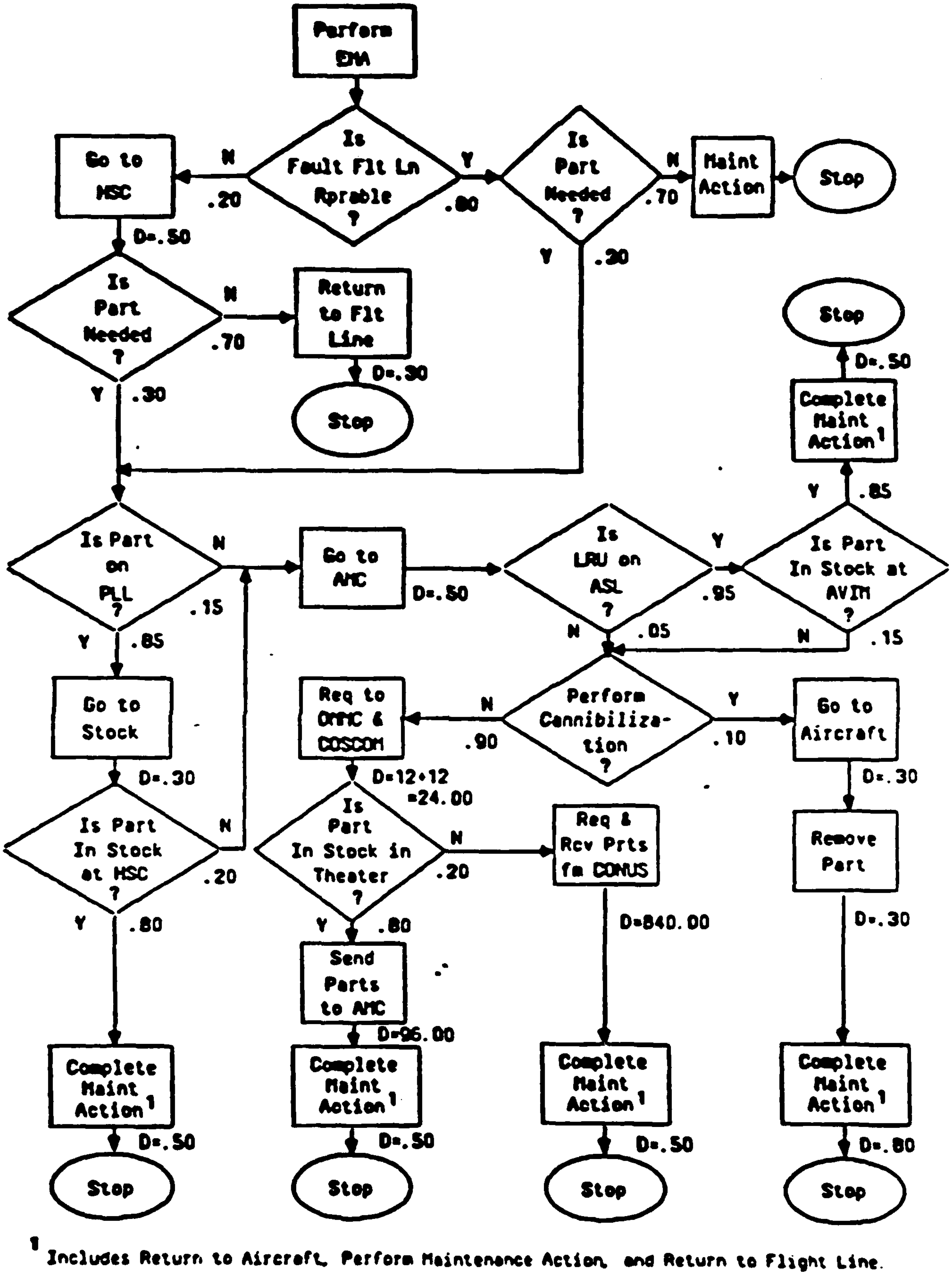

Figure 16. Wartime ALDT model.

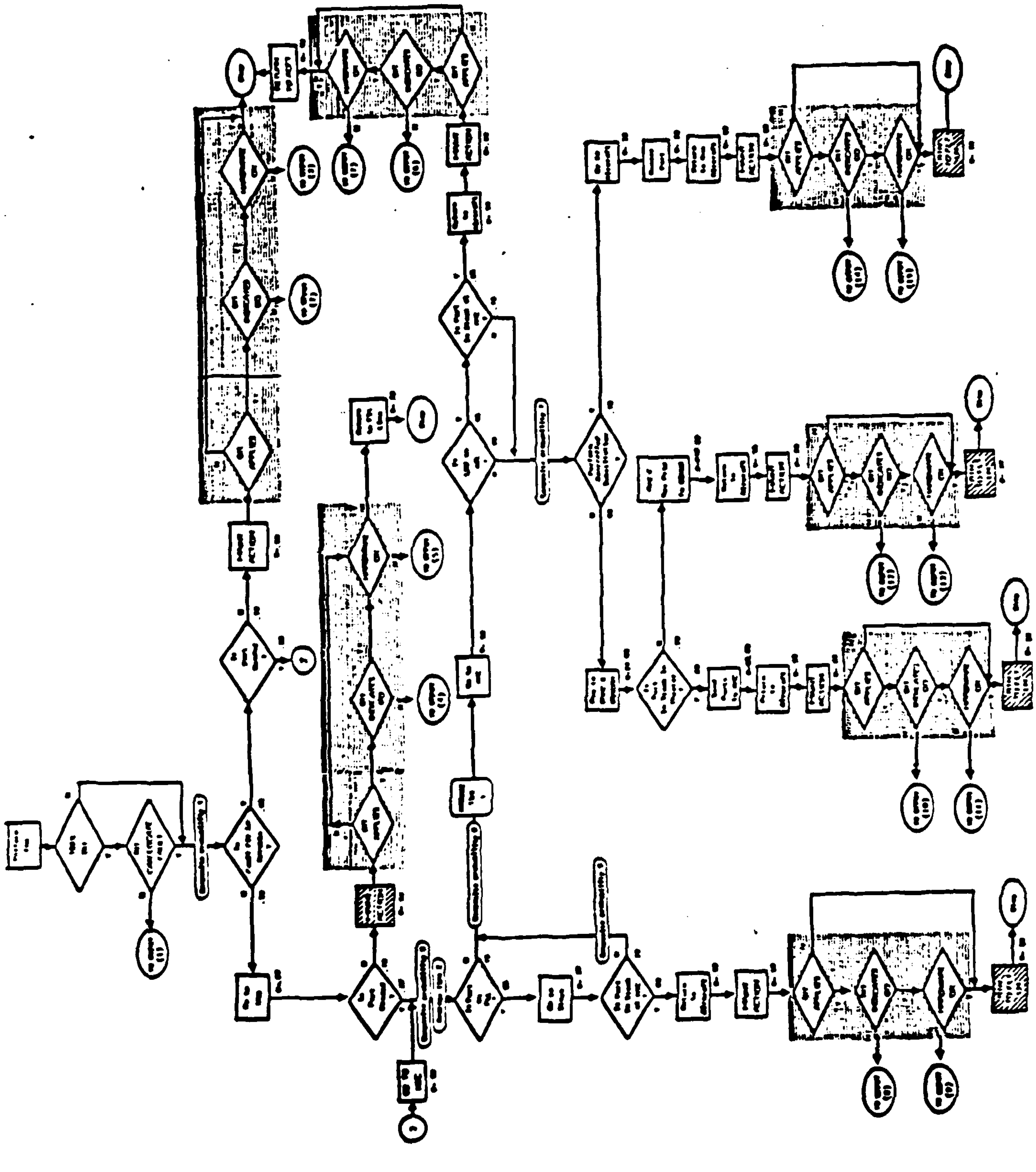

Figure 17. Wartime ALDT with BIT.

action or faulty replacement LRU. Therefore, the probability of this event is equal to the probability of an isolation error.

To compute the expected value of the total down time once an EMA had occurred, the probabilities for each of the BIT decision blocks and the delay and repair times associated with depot maintenance were treated as variable inputs. The probabilities and times associated with the decisions and events from the original ALDT model were held constant. The model outputs are:

(1) Cumulative probability that depot maintenance will be required once there is an EMA.

(2) The expected value of the total maintenance time required for depot maintenance.

(3) The expected value of total administrative and delay time associated with depot maintenance.

(4) Aircraft availability.

(5) Maintenance ratio.

(6) The expected value of the total down time associated with each discreet path within the model.

In applying the model, a base set of inputs was established from a subjective evaluation of the military experience to date. The base case was intended to be a conservative estimate from which to conduct a regression analysis of each of the BIT failure types. During the regression analysis one failure type was systematically varied while all other inputs were held constant to determine the effect of the BIT failure on mission capability. In addition, one run was made changing the probability of all types of BIT failures to zero to establish for comparison purposes conditions created by perfect BIT.

<u>Summary of Results</u>

The EAM model was used to project aircraft availability for the LHX for various levels of BIT performance and to examine the sensitivity of the availability measure to different types of BIT failures. The modeling effort was performed using an attack helicopter company as the sample organization. The base case mission profile was to perform two back-to-back, 3 hour, eight aircraft missions in each 18 hour cycle for a 7 day period. The results of the modeling effort indicate that 11 SCAT helicopters employed in an attack helicopter company flying the sample mission profile will achieve an availability ranging from 68% for perfect BIT to 59% for BIT with performance equal to the AH-64.

The results of the sensitivity analysis are depicted in Figure 18. In each case, the start point is the AH-64 base case, then one factor (either failure mode or down time) is improved

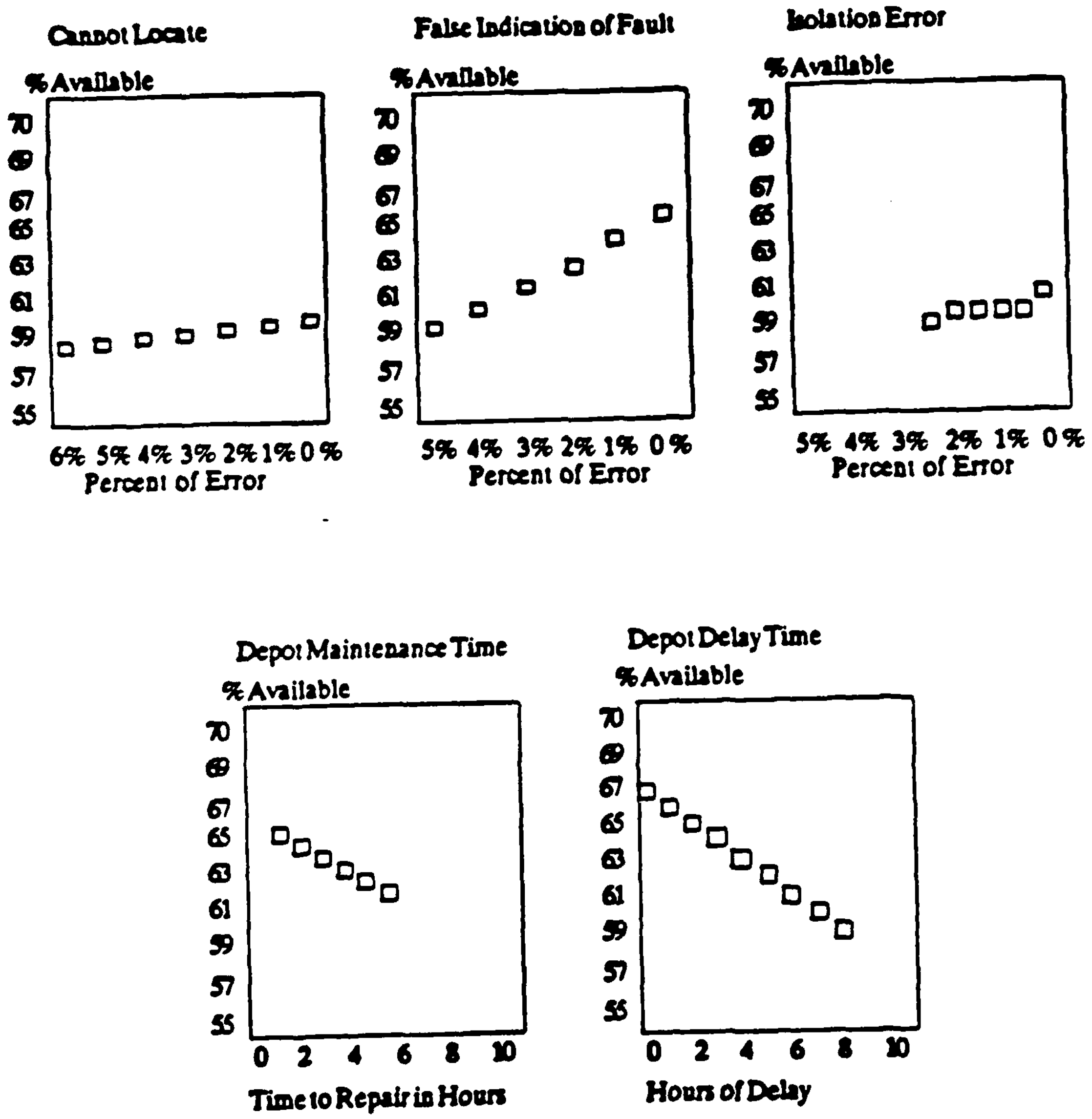

Figure 18. Sensitivity-Aircraft availability to BIT performance.

while each of the other factors are held constant. It is important to note that the factors illustrated in the graphs are interdependent and therefore, the graphs are comparative not additive. That is, it is not possible to add the improvement gained with one factor to the improvement associated with another factor to obtain a total improvement in availability.

As the graphs indicate, the largest opportunity for improvement, approximately eight percentage points, lies in the delay times associated with depot maintenance. For every hour of delay that is avoided, there is a 1% improvement in aircraft availability. The second largest opportunity for improvement, approximately six percentage points, lies in the percentage of error associated with the false indication of a fault failure mode. On the other end of the spectrum is the failure mode in which the BIT cannot locate the faulty LRU. Totally eliminating this failure while holding all other parameters constant at the base case value, will achieve only a 1.4% improvement in aircraft availability.

<u>MPT-Related Solutions</u>

There are several MPT-related remedies which can mitigate the impact of BIT failures. However, they are generally not applicable to repair time. The time required to repair a fault is generally inherent in the design. Usually the physical space and the nature of repair tasks preclude cutting repair time by adding people. On the other hand, reducing administrative and logistics delays is extremely sensitive to the positioning of personnel. In the event that there is a BIT failure the more quickly the repairer can be made available, quite obviously, the shorter the down time. In the case of the LHX, as the delay time awaiting depot maintenance is adjusted downward to 0, the expected value of the total down time for an EMA goes from a high of 7.1 hrs to 5.7 hrs. That translates into an improvement in aircraft availability of approximately 8%.

There are several options available to reduce the time awaiting depot maintenance. The first is to form contact teams that can be deployed rapidly to the defective aircraft. This option does not conflict with the 2LM concept proposed for the LHX. It would, however, require an investment in portable ATE. Another potential difficulty on the modern battle field will be communicating between the aircraft owning unit and the depot maintenance activity to request the team and to advise them of the aircraft's location. The combination of communication and mobility limitations on the battlefield make it unlikely that the delay time could be reduced to much less than four hours using this option.

Another remedy would be to amend the 2LM concept and position highly trained diagnosticians at the AMC, the Aviation Battalion HSC and perhaps the helicopter company. This option is extremely effective in reducing the delay time but is expensive

in terms of the increased training burden associated with training more military personnel in diagnostics and perhaps piece part repair and the personnel management burden associated with maintaining visibility of and control over these scarce assets. The other major drawback to this option is the proliferation of off-aircraft test equipment.

The final option for discussion is, in reality, carrying the training of specialized diagnosticians to the extreme and training every mechanic to conduct off line trouble-shooting. This option would have maximum impact on the delay time but would also be the most expensive in terms of training and off-aircraft test equipment. The wholesale expansion of training would also be exacerbated by the retention problems that normally occur when relatively junior soldiers (E-5 and below) are extensively trained.

The best solution will probably be a hybrid of the three mentioned above. As was pointed out earlier, as a rule of thumb, 20% of the system causes 80% of the maintenance workload. Therefore, placing some diagnostic capability in the unit and gradually increasing it as you go up the maintenance chain culminating in highly mobile contact teams at depot level will probably be the most cost effective. This solution would provide the opportunity to hold the training burden and proliferation of the training burden in check while concentrating on the relatively small portion of the aircraft that most affects the aircraft's availability.

Evaluation

The EAM research effort was very successful in meeting the basic research objectives. The literature search conducted in Phase I of the project provided a wealth of data indicating that BIT had consistently failed to reach developmental goals. These findings were consistent across a wide range of systems and across all branches of the armed services. The new analyses conducted with data from systems most relevant to the LHX were consistent with findings from the literature review.

It must be noted, however, that limited access to highly sensitive LHX specific data which may be considered proprietary caused the research team to reexamine the goal of estimating the expected performance of the LHX BIT and to focus their analytic efforts on modeling the impact of various levels of BIT performance on LHX availability.

An objective evaluation of the project must also recognize the prototypical characteristics of the model developed to conduct the LHX analyses. The model was limited to providing data regarding aircraft availability and did not directly examine manpower impacts of BIT performance. The impacts of BIT performance on manpower and personnel factors were examined subjectively in the EAM research effort. Furthermore, the model

was specific to the LHX and had little generalizability to other systems beyond application of the logic behind the model.

The MANCAP model, which was developed after the conclusion of the EAM project, may provide a much more sophisticated method for examining issues related to BIT performance impacts. For example, if the possible BIT failures were integrated into the MANCAP model, quantitative projections for both aircraft availability and manpower effects of BIT performance could be investigated.

Unit Training

Introduction

One of the three major factors to be considered in the MANPRINT supportability analysis step in the SIMM is training. Typically, training requirements for a new weapon system are not considered until late in the system acquisition cycle. Even then, the focus is on the training of single operators or training at the crew level. Furthermore, the training requirements are typically analyzed for only the new weapon system with little or no attention devoted to the issue of training requirements created during the transition from predecessor systems to the new system.

For a major weapon system such as the LHX, the period of actual fielding of the system extends for several years. It is during this transition period that the Army will experience the greatest challenge to its training system. This challenge arises from the requirements to train for the new system being fielded as well as predecessor systems already in the Army inventory. Successful planning for this transition period will reduce or eliminate training resource conflicts or shortages and accelerate the speed at which units reach acceptable training levels after receiving the new systems. Ineffective or inadequate planning will reduce unit readiness through the creation of problems such as delivery of systems to units lacking appropriate training, delays in system delivery until training is conducted, or mismatches such as training of new soldiers to maintain the new system and then assigning them to units with predecessor systems because the new systems have not yet been delivered. This training challenge exists for both operators and maintainers of the new and predecessor systems.

The obvious solution to problems noted above is to begin planning for a unit training program early in the design stages of a new weapon system. At that point, it may be possible to identify potential training resource conflicts which can be solved by altering the design of the new system to include embedded training features or other system design innovations. Such early-on analyses require a training analysis and planning method that allows one to examine training resource requirements at various levels ranging from the individual soldier to the

battalion level or higher. Furthermore, the method must be capable of examining a wide range of training resources from classrooms and instructors to simulators and live-fire ranges. The method must also be dynamic in the sense of examining training resource requirements over time and across units and organizations.

A number of training analysis methods currently exist within the DoD community. The Instructional Systems Development and System Approach to Training methods have been employed by the Army for many years. The first phases of these methods focus on the identification of training requirements which can be used to design and develop training programs. Unfortunately, these methods are designed for use in an environment in which specific tasks and user performance requirements can be articulated, and these conditions do not exist during the concept development phase of a major weapon system acquisition program. At that point, the weapon system which will define the maintainer and user tasks is still a concept, and has no design or blueprint.

HTI felt that the limitations associated with the lack of a specific weapon system design could be used to establish parameters for the design of an early-on training analysis method. Upon review, identified limitations suggested that the most appropriate approach was to develop a method which would allow the analysis and comparison of alternative training strategies, rather than development of a method to design detailed training programs. The requirements for development of an early training analysis method combined with an understanding of the general conditions existing during the early phases of any major system acquisition program have led to the formation of a specific set of research objectives for a unit training model effort. These objectives are discussed below.

Research Objectives

The overall purpose of the unit training[3] and displaced equipment training (DET) research was to investigate and develop methods and models to facilitate and enhance training planning during the acquisition of new weapon systems. In keeping with the ARI philosophy of conducting MANPRINT research that provides immediate benefits to the Army, the project was to focus on the training aspects of the LHX acquisition program. The LHX program was to serve as the frame of reference for acquisition procedures, milestones and timing of events. Additionally, the prototyping of the methods and models was to contribute to the development of the LHX program. Therefore, the second general purpose of the research effort was to contribute to training planning for the LHX.

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[3]"Unit training in the context used throughout the report is that initial training a unit receives on receipt of new equipment and is not sustainment training.

The scope of the research effort was limited to the design and demonstration of a prototype training analysis model. In establishing the boundaries for the research it was determined that the unit training project would examine two aspects of training that emerge during the proof of concept phase of a weapon system's acquisition. The two aspects of training to be examined were: (1) the assessment of training resource requirements associated with the concepts for unit training of organizations to be equipped with the new system and, (2) qualification training for the individuals in units which will receive the equipment that is displaced by the new acquisition. Displaced equipment training includes the development and assessment of concepts to accommodate the special considerations for training in the reserve components.

It is important to note that the scope of this effort did not include the analysis of institutional training requirements. The focus was on unit training. Although the method and models were intended to have generic application, this effort excluded individual institutional training for the new weapon system except as the institutional training could be identified to be competing for the same or similar resources as unit training.

For the purposes of prototyping, the method was applied to the LHX program to devise a fielding schedule that adhered to the proposed procurement schedule and distribution plan and was operationally effective. The schedule sequenced units into a unit training program that was devised to optimize the overall unit training time and resource requirement. In addition, the method was applied to individual qualification training for personnel assigned to units that will receive the OH-58 and AH-1S helicopters displaced by the LHX.

Research Approach

The research team for the unit training effort used a five step[4] approach in conducting the model development and test application effort. The five steps included:

1. Definition of Desirable Method Characteristics
2. Identification of Training Requirements;
3. Model Development;
4. Model Application; and
5. Analysis and Comparison of Training Schedule Alternatives.

Step 1 was the general identification of desirable model characteristics based on analysis of the LHX acquisition environment. The result of the effort was a delineation of a

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[4]A separate report by Lindquist, Robinson and Statler (1987b) listed only four major steps (i.e, Step 1 of this report was omitted in the separate report).

top-down analysis approach. Step 2 was the specification of steps to determine training requirements which were then applied to the LHX. Steps included identification of the target audience scheduled to receive the LHX, determination of the training required, and estimation of the resources needed. Step 3 was a model development stage in which procedures were outlined and tested to compare the relationships between the training required, resources required, and an effectiveness measure. In Step 4, training schedule alternatives specific to the LHX were identified by varying parameters such as location, pre-positioning TOE equipment, and combining selected training components.

Application of the prototype training planning method to the LHX was done concurrently with and was an integral part of the development of the computerized training planning models. The nature of the project was such that at times the information available drove the architecture of the model and at other stages the demands of the model established the requirement for specific elements of data. There were two distinct applications attempted. The first developed an optimal unit training schedule for the LHX that adheres to the proposed procurement schedule and distribution plan. Subsequently, the method was applied to investigate the individual qualification training required to staff reserve units scheduled to receive the OH-58 and AH-1S helicopters displaced by the LHX. The LHX program lends itself well to the prototyping role because it is sufficiently complex to exercise the method fully.

The primary driver of the model development and application steps of the method was the investigation of training requirements of units scheduled to receive the LHX. It was determined that units receiving the LHX were good candidates for top-down demonstration because the LHX program is still under development, and unit training requirements for the system have yet to be defined and are dependent upon the technology incorporated into the system. The top down approach employed to develop the model was consistent with the lack of detailed definition for the system's training requirements. Furthermore, it provided the opportunity to develop a model capable of integrating a higher level of detail as more information regarding the LHX becomes available.

The computer model was then applied to several alternatives developed to investigate the relative sensitivities of the various elements such as resource demands, start times, and areas of training. This process was reiterated until the desired training effectiveness level was achieved within the stipulated resource constraints or until the opportunities for improving each alternative were exhausted.

Step 5 was the analysis of the model outputs in terms of effectiveness and resource efficiency. The result was a viable training plan or set of alternative plans for transitioning a new

weapon system (specifically, the LHX) into the Army force structure. As the LHX development process continues and information becomes more precise, the process may and should be employed to update the results and further refine the model.

As noted above, there were five steps to unit training model development; four contained application components tested on LHX issues. Each of these five steps is described in more detail in the paragraphs below, for both model development and sample application to the LHX.

Step 1 - Definition of Desirable Method Characteristics

The primary purpose of the unit training effort was to develop a method that would be useful in supporting training analyses in the earliest stages of a major system acquisition program. The LHX program was analyzed as a sample acquisition program to determine the environment in which the method could be utilized. The research team had a great deal of general knowledge regarding the LHX acquisition program as a result of their involvement in other aspects of the LHX MANPRINT Research Program. In addition to the general knowledge gained through working on the overall LHX MANPRINT effort, the research team held meetings specifically with representatives from the Army Aviation School at Fort Rucker to identify their training analysis requirements for the LHX program.

As is the case in all traditional acquisition programs, the design of the LHX system had not yet been finalized during the concept development phase of the acquisition cycle. For this reason, data required to conduct traditional forms of training analysis did not exist. The representatives from the Aviation School indicated that the method would be most helpful if it would aid them in evaluating the resource requirements and potential resource conflicts and shortfalls that would develop during the fielding of the LHX system. Thus, the members of the LHX community most directly involved in training identified training planning and scheduling during fielding as the most appropriate focus of the method to be developed in this research effort.

The desired characteristics of the models developed were outlined as a top down approach to enable effective training planning before detailed system data were available, flexibility to accept changes and refinements as the system matures and data become more specific, and simple and relatively fast operation so as to enable the exploration of training schedule alternatives without the need for consensus among the acquisition community, thus preventing the premature foreclosure of options.

Step 2 - Identification of Training Requirements

In designing the model, several critical steps were outlined for use with proposed systems, and tested through application to

the LHX acquisition process. The first area outlined in need of training identification for new system acquisition was the types of organizations scheduled to receive the new system and the system's predecessors. The next requirement's step was defined as the investigation of the comparability of existing systems and the emerging system. Where appropriate, existing training concepts and plans would be adjusted to accommodate the new system and to incorporate advances in training technology. If the introduction of entirely new technology demanded it, original training concepts would be formulated. The concepts would then be grouped according to common characteristics and merged into a single cohesive outline of the training required for the new system. Training resource estimates would then be developed in a similar way, retaining the applicable requirements from the predecessor systems and adjusting as necessary to implement the updated training outline. The result would include the collective tasks inherent in the unit's mission and the training resources required to perform one iteration of each task. Successful accomplishment of this phase included detailed research into training literature for current systems such as Army training and evaluation programs (ARTEPs), soldier training publications, and mission and function statements as well as a diligent investigation of the requirements for, and characteristics of the emerging system. The latter included the entire body of studies, plans and reports required by the acquisition system, and current literature on the technologies being applied.

The application of the model to the LHX, and the accurate estimation of the unit training needed for all units receiving LHX aircraft required the identification of the numbers of unit types receiving the system. For example, from an examination of the Draft LHX Distribution Plan (U.S. Army, 1986), it was determined that 54 attack, 53 utility, 62 reconnaissance, and 16 medevac units were scheduled to receive LHX aircraft. To avoid the need for a security classification, it was necessary to develop training plans in accordance with the procurement schedule without reference to specific individual units or areas of location.

After consolidating the data in the draft LHX Distribution Plan, an investigation was made of the comparability of the predecessor systems to the LHX. In the case of the LHX, the predecessor systems examined were the AH-1S, OH-58, UH-60, UH-1, and the AH-64. These systems were selected for the comparability analyses in order to represent the spectrum of missions to be performed and to approximate the level of technology of the LHX most closely. Although the AH-64 (Apache) and UH-60 (Blackhawk) are not light helicopters and will not be displaced by the LHX, training references were reviewed for the Apache and Blackhawk aircraft because they were the most technologically advanced in comparison to the LHX. From the review of predecessor system training documents, the unit training requirements for each system were determined and

compared to the general training requirements of the LHX. Specifically, the question was asked whether the missions still exist and do the applications of advanced technology change the inherent tasks or methods of training for those missions? Therefore, LHX documents including the Individual and Collective Training Plan for the LHX (USAAVSCOM, 1985a), Volume II of the LHX Draft Required Operational Capabilities (USAAVNC, 1985a), and the LHX FSD RFP (USAAVNSCOM, 1986c) were examined to determine training differences between the LHX and predecessor systems. The examination of LHX documentation provided for the incorporation of new training concepts brought about by advances in training technology. Although many of the skills, knowledges, and individual tasks will change, there is no indication that there will be any significant changes in the collective training tasks for the LHX. For example, the automated cockpit will change gunnery tasks but primarily from an individual as opposed to a collective training perspective.

The training requirements for each type of LHX unit were grouped into training outlines that specified the training required for a particular type unit to achieve full mission capability. The investigation indicated a high correlation between LHX and AH-64 unit training. Therefore, the AH-64 unit training phases were perpetuated as:

- Phase I - Individual and Crew Training
- Phase II - Company and Unit Training
- Phase III - Gunnery Training
- Phase IV - Battalion Training
- Phase V - ARTEP

Although the aircrew qualification course (AQC[5]) is not considered collective training, it was considered throughout the effort for its resource impact on other phases of unit training. Based upon information in the AH-64 Unit Training Plan, it was estimated that the five phases of unit training and AQC for the LHX, would be accomplished in a 20 week time frame. Figure 19 is a timeline displaying the training outline for a typical LHX equipped unit. For the purposes of this analysis, a unit is a company-size organization. It is important to note that although all LHX unit training can be catalogued into one of the five phases, there are some units that do not undergo training in each of these phases. For example, most of LHX utility units do not perform battalion level training. Also there are two TDA (Table of Distribution and Allowances) units scheduled to receive LHX utility aircraft and these organizations only perform individual AQC.

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[5]AQC, as used throughout this report, refers to individual training which both officer and enlisted personnel receive to become MOS or ASI (Additional Skill Identifier) qualified on the new equipment.

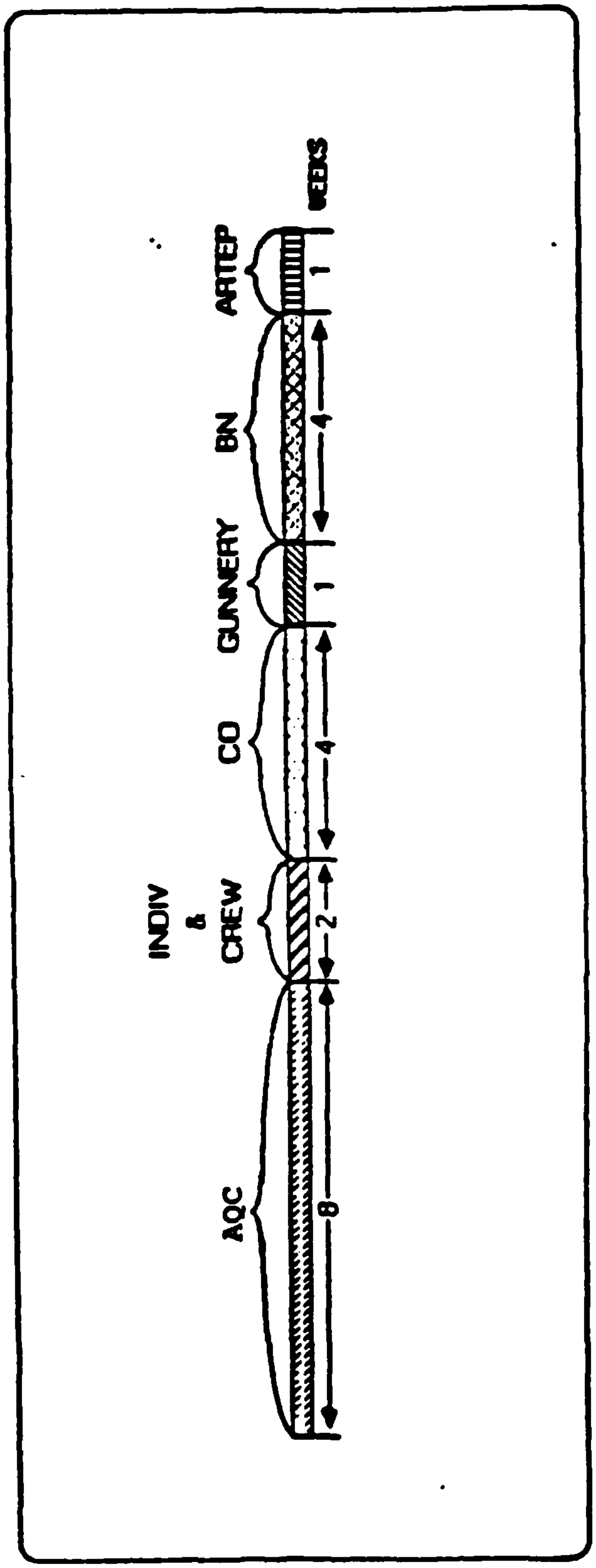

Figure 19. Timeline of training outline.

Training resource estimates were established in much the same way by re-examining the requirements for the predecessor aircraft systems for applicable resources and adding resources specific to the LHX. They were then combined into packages sized to implement a single iteration of each of the training outlines. Resources that were specific to the LHX included the tactical team trainer, the integrated training system for the LHX, and the Dummy Stinger.

Table 11 illustrates the resource packages identified for each of the different LHX missions. A total of 19 resource packages were identified for LHX units performing attack missions. A total of 20 resource packages were identified for the units performing utility missions. An examination of predecessor system documents revealed that training for units performing reconnaissance missions required the same resources as training for units performing attack missions. The same was true for utility and medevac units. Therefore, throughout the rest of this discussion, the training outlines for attack units and utility units apply equally to reconnaissance units and medevac units respectively.

Table 11

Resources Required for LHX

Required Resources Identified for LHX Attack and Reconnaissance Missions	
Maneuver Area	Dummy Hellfire
Classroom and Briefing Rooms	Dummy Stinger
Airfield and Stagefield	ATGM (AntiTank Guided Missile) System
Garrison Facilities	Flying Hours
Aerial Gunnery Range	External Aircraft
Opposing Forces (OPFOR)	External TOE Equipment
Friendly Forces	Maintenance
Evaluators	Supply
Integrated SCAT Training System	Tactical Team Trainer
MILES/AGES (Multiple Integrated Laser Engagement Simulation/ Air-to-Air Ground Engagement System)	

Table 11 (Continued)

Resources Required for LHX

Required Resources Identified for LHX Utility and Medevac Missions	
Maneuver Area	Dummy Hellfire
Classroom and Briefing Rooms	Dummy Stinger
Airfield and Stagefield	ATGM System
Garrison Facilities	Flying Hours
Aerial Gunnery Range	External Aircraft
OPFOR	External TOE Equipment
Friendly Forces	Maintenance
Evaluators	Supply
Integrated Utility Training System	Tactical Team Trainer
MILES/AGES	RCMAT

Step 3 - Model Development

The third step in developing a method to estimate the unit training requirements of emerging systems was to model the cumulative relationships of training resources to training requirements and to develop an algorithm to determine the most program-effective and resource efficient method of transitioning units receiving new weapon systems.

Modeling Objectives. The primary objective of this step was to measure the relative effectiveness of training schedule alternatives. Specifically, it was determined that the model should demonstrate the relationships between training requirements and training resources. As part of the process, the model required calibration in addition to the training outlines developed in Step 2. Calibration was to be accomplished by the identification of resources and rates of consumption required to support one repetition of the training outline. In turn, the outline could then be expanded to include provisions to complete training for the entire transition program. The result of application would be an initial training schedule to be used as a base case. In order to facilitate later comparisons of alternatives, the base case was designed to be intentionally simplistic and avoid complex sequencing or combinations of resources.

The base case was also designed to serve as a departure point for the development of training schedule alternatives. According to model design, the alternatives were to be generated by varying the sequence, combinations of resources, or location of training in ways that appear to present opportunities to

enhance effectiveness or reduce resource requirements. The model functions then served as a computer supported data filing, manipulation, and aggregation system used to evaluate the alternatives.

Model Structure. The basic modeling scheme was a variant of an input-output (Leontief) structure. An input-output structure was chosen because it permitted rapid fidelity in the treatment of resource requirements and was sensitive to differences in training schedule alternatives. Leontief structures typically allow for electronic case filing to foster reproducibility and rapid modular correction and update capability. Due to the tentative nature of the problem, it was necessary to employ a structure that allowed for easy modification and maturation as additional information about the developing system was obtained.

Other features of the input-output structure utilized in this effort included: the ability to deal with constraints easily, the ability to develop feasible alternatives, and the ability to identify the key drivers and limiting constraints of different alternatives. It also provided the ability to present trade-offs graphically among and within the various alternatives.

In the model developed, inputs for each training requirement included the training required, the training resources required, and the rate at which training resources were consumed. The model was then designed to aggregate this information for multiple resources, organizations, and training requirements and establish the resources required for an organization to accomplish training in a given time frame.

The physical structure of the model ended with essentially four components. These were training resources, training requirements, type of resource consumption, and time. The first model element consisted of two arrays crossfiling the training requirements and rates of resource consumption. These arrays, generated from the model, would then be stored in such a way that the information could be manipulated and aggregated with respect to time in the second element of the model. The second element was also to be stored in an array and converted to the training requirements, resource requirements, and the rate of consumption into a schedule of training required for each organization in calendar time periods. In outlining the procedures for model application, it was planned that these would be aggregated to provide the total amount of resources required for a certain period of time or during a specified time interval.

An objective of applying this step of the model to the LHX training system was to develop an effective and resource efficient plan for conducting unit training of the LHX as well as to test the array and aggregate procedures. To that end, the training outlines developed in the application of step 2 procedures were expanded to include the resources and rates of consumption necessary to support the training required in the

outlines. The model converted the outlines and resources to a file containing total training required by week for the entire program. The aggregation of training outlines into a single proposed training schedule represented the base case from which alternatives were developed.

An example of the model applied to a simple case in which only one resource was considered for three units is described below. In this case, the resource under consideration was "maneuver area." Figures 20 through 22 present the number of maneuver areas needed for each phase of unit training for three different units respectively. In this case, unit 001 and 003 required one maneuver area for each phase of training, except gunnery. Unit 002, a utility unit, required maneuver areas for all phases except the gunnery and battalion phases of training.

The three units were then combined, as shown in Table 12, to illustrate the amount of maneuver areas needed for each week of the training cycle during each of the training phases. Unit scheduling was to begin at the first full week after the aircraft were delivered to the unit. Table 12 is displayed in Figure 23 where each bar represents a unit's requirement for maneuver areas throughout the training cycle. Figure 23 further illustrates the possible conflicts where multiple units would be competing for the same resource. In this example, the start time of unit 003 in Figure 23 could be shifted eight weeks to the right in order to reduce the conflict of maneuver areas between unit 001 and unit 003. This example can be expanded to include all units receiving the LHX and all resource packages necessary to complete one repetition of the training cycle.

The base case outlined demonstrated the relationships between the training required and the training resources needed to transition LHX units. In keeping with the objective of developing a base case that was simplistic and avoided complex sequencing of training events, the base case used for the LHX was one in which all units performed all unit training with the exception of gunnery (Phase III) at their home stations with TOE equipment. Gunnery training required ranges and firing areas which were not usually available at each unit's home station.

Figure 24 displays the base case for the fielding of the LHX in fiscal year (FY) 2000. FY 2000 was chosen as the slice to be investigated because it is the year in which the greatest number of LHX aircraft will be fielded and thus will present the most difficulty when planning unit training. The schedule displayed in Figure 24 was based upon the Draft LHX Distribution Plan (U.S. Army, 1986). Units were scheduled to begin individual and crew training (Phase I) at the earliest possible start time (ie., upon receipt of equipment). From that point a period of 10 weeks was added preceding Phase I training for AQC[6] training.

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[6]AQC is identified by the letter "N" in Figure 25.

	AQC	INDIV/CREW	CO	GUNNERY	BN	ARTEP
MANEUVER AREA	1	1	1	0	1	1

Figure 20. Maneuver area required for unit 001.

	AQC	INDIV/CREW	CO	GUNNERY	BN	ARTEP
MANEUVER AREA	1	1	1	0	0	1

Figure 21. Maneuver area required for unit 002.

	AQC	INDIV/CREW	CO	GUNNERY	BN	ARTEP
MANEUVER AREA	1	1	1	0	1	1

Figure 22. Maneuver area required for unit 003.

TABLE 12

Maneuver Areas Required During Training Cycle

PHASE / WEEK	AQC	INDIV/ CREW	CO	GUNNERY	BN	ARTEP
1	1					
2	1					
3	2					
4	2					
5	3					
6	3					
7	3					
8	3					
9	2	1				
10	2	1				
11	1	1	1			
12	1	1	1			
13		1	2			
14		1	2			
15			2	0		
16			2	0	1	
17			1	0	1	
18			1	0	1	1
19				0	1	0
20				0	1	1
21					1	0
22					1	0
23					1	0
24						1

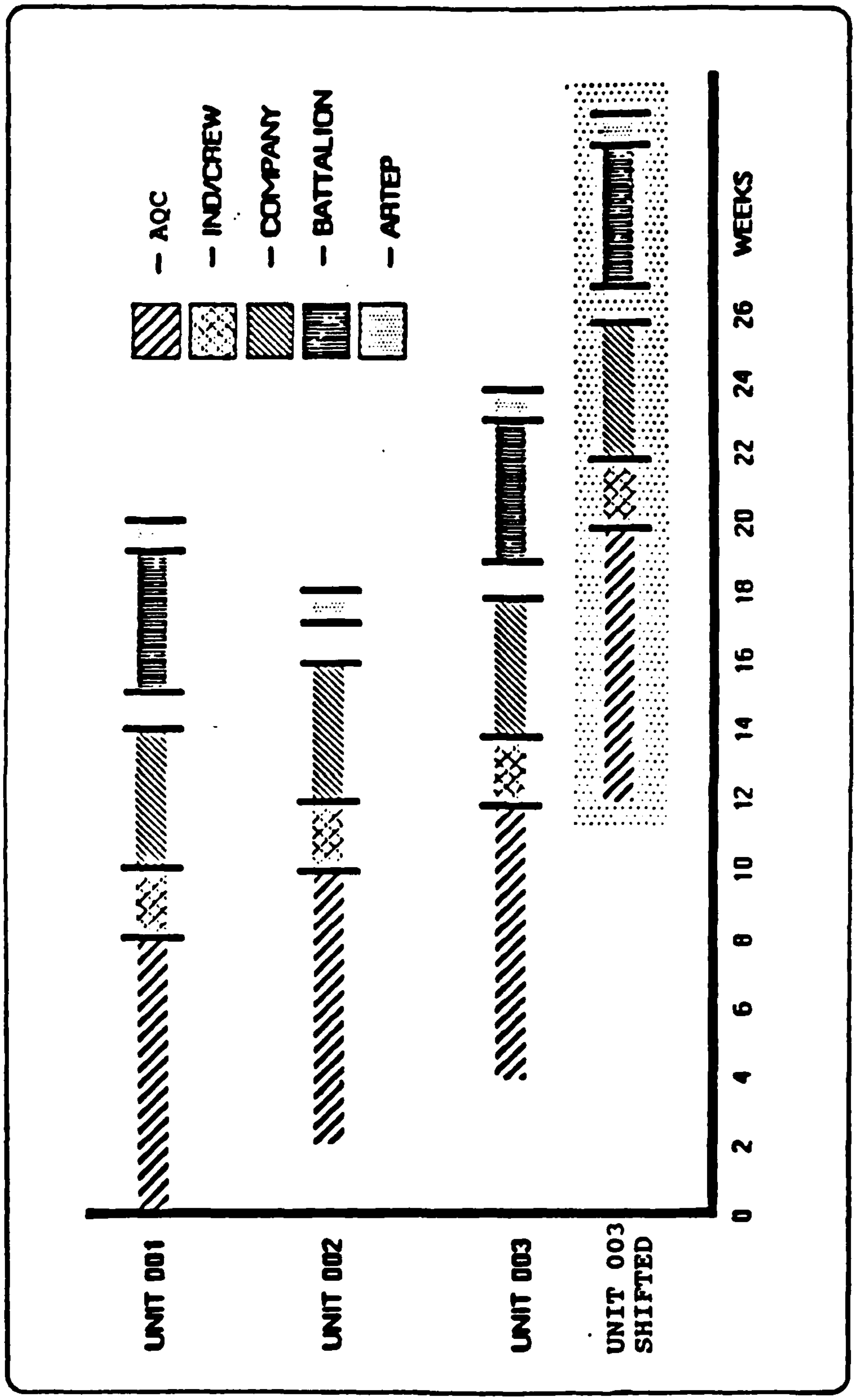

Figure 23. Training outline for three sample units.

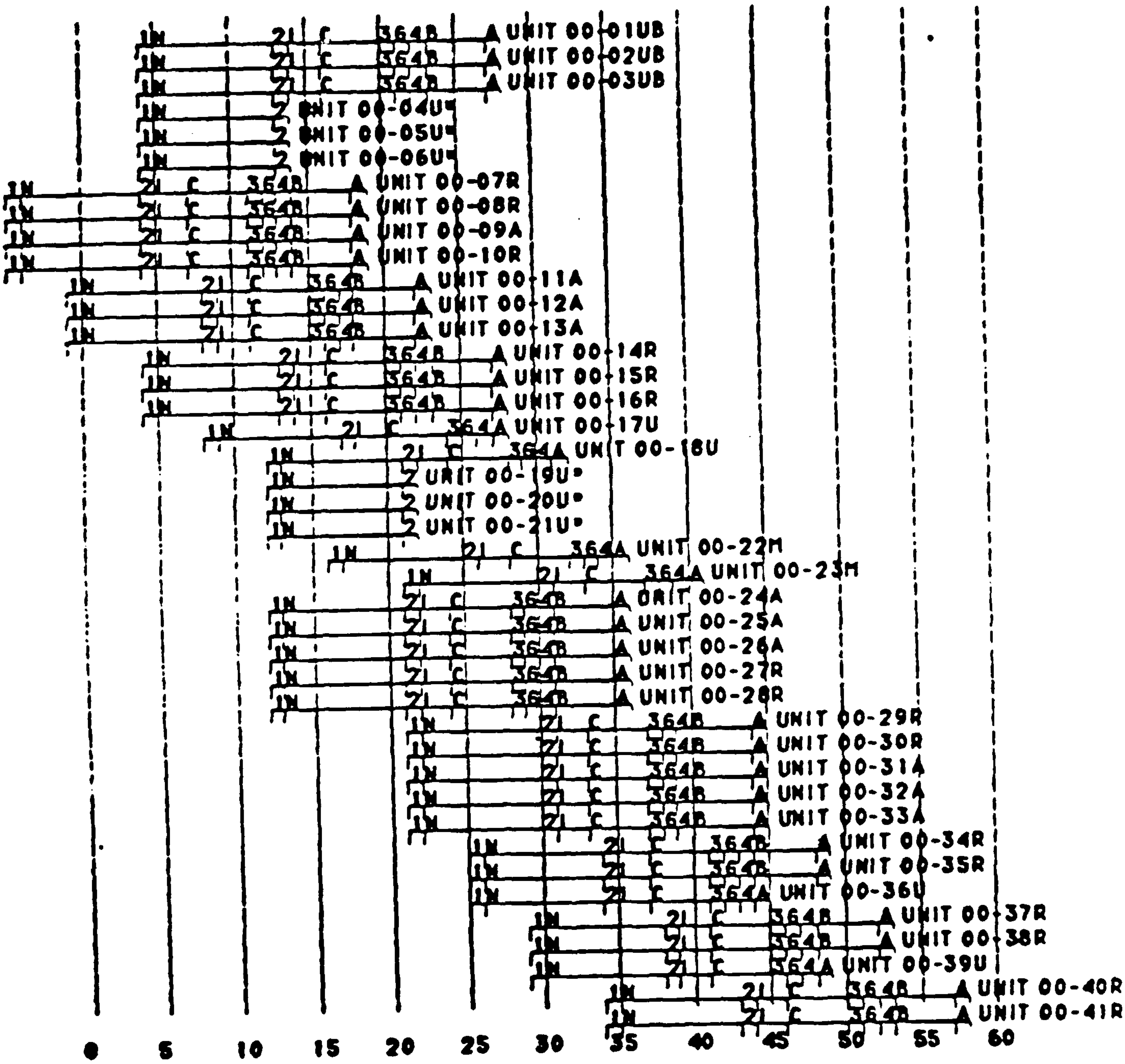

Figure 24. Training schedule for the LHX in FY 2000.

This 10 week period allowed 2 weeks for travel time to and from AQC. As outlined in Figure 24, LHX unit training in FY 2000 will be accomplished in 58 weeks with an average unit training time of 24 weeks.

The next step in the model development process for the LHX was to identify the critical resources to be examined for the base case and throughout the analysis of each alternative. For application to the LHX, the critical resources were identified based upon the subjective consideration of cost, real world availability, and impact on training. The following is a list of the critical resources identified for LHX unit training in order of descending importance:

1. Administrative time;
2. Flying hours;
3. Aerial gunnery range;
4. Maneuver area;
5. OPFOR;
6. External aircraft;
7. External TOE equipment;
8. Tactics Team Trainer; and
9. Door gunnery range.

In the initial application of the base case, there was a conflict within 10 SCAT units (attack and reconnaissance) because Christmas falls within weeks 10 and 15. Historically, TRADOC has not conducted training over the Christmas holidays nor is it operationally practical to conduct training during the Christmas holidays. Therefore, the base case was modified to allow for a two week administrative period for those units scheduled for training during this time. This rationale was also applied to the utility units since the holidays affect seven utility units.

When allowing for a break in training for the holidays, 15 SCAT units were affected. More than 50% of SCAT units completed training in 37.9 weeks and the average unit training time was increased from 24 weeks to 24.8 weeks. Nine of the 15 utility units were affected by the 2 week down time during the holidays. Allowing for the 2 weeks of down time, 50% of utility units completed training in 28.7 weeks and the average unit training time was 17.2 weeks.

Allowing for a break in training over Christmas, there remained a large number of units attending AQC at one time. Specifically, there were 17 units scheduled to be attending AQC at week 21 which would require a 40% improvement in the student to aircraft ratio over the current student to aircraft ratio for the AH-1S aircraft. Such an improvement was not likely. Therefore, the base case was refined again to reduce the number of units attending AQC at any one time.

The other nine critical resources were comparatively examined for the base case. Upon examination, no substantial

conflicts were identified that could be deconflicted in such a way as to reduce training burdens and maintain a reasonable unit training time. This finding was in keeping with the definition of the base case of simplicity and maximum independence among training requirements.

Step 4 - Model Application

Step 4 of the method development involved the specification of steps for the outline of alternatives and application of the procedures model developed in Step 3 to those alternatives. The alternatives were designed to be derived from the base case training outline by varying the major parameters such as location, sequence, or adding and deleting resources or requirements. Alternatives constituted separate and distinct training outlines. The next step outlined was the varying of parameters within alternatives to assess the sensitivity of the training requirements and to maximize their efficiency and effectiveness. Modifications could include variations in start dates for individual units, trade-offs between training resources, and changes in constraints.

The next step in the model was a comparison of each alternative across organizations to be trained to determine the critical resources demanded. Critical resources were those identified as necessary to maintain system operability at established levels. Following this step was the identification of critical resources based on a variety of subjective considerations including factors such as cost, real world availability, and substitutability. Any conflicts in demand for resources and any resources for which substitution were feasible were to be identified at this point. An example of conflicting resources would be two or more units requiring use of a gunnery range at the same time. An example of a substitutable resource would be the use of an aircraft simulator for actual flying hours. Once the critical and conflicting resources were identified, each alternative was to be refined to deconflict the resources and still accomplish the training required on an acceptable timetable. The process of resource deconfliction would be reiterated until all resources were deconflicted or until no more deconflictions could be made without violating the developing system's constraints.

After refinement and calibration of the model for the LHX trial application, three unit training schedule alternatives were developed for each type of LHX unit. They were derived from the base case by varying the location of training from home stations to area training centers, pre-positioning equipment, eliminating training Phases I and III, and combinations of these alternatives.

Sensitivity analyses were performed on each of the three alternatives and the base case in an attempt to deconflict critical training resources and to provide unit training to the

largest number of units in the smallest amount of time. These analyses were done for the LHX by varying unit start times for training, and varying administration time within a training cycle. This process of resource deconfliction and reduction was repeated for each of the three alternatives as outlined in the following discussions.

Alternative 1. Alternative 1 was derived from the base case by eliminating Phases I and III from the unit training schedule. In this excursion, an examination was made of the resource and training time impact when individual and crew, and gunnery training was conducted during AQC. Figure 25 illustrates this alternative before any deconfliction analyses were performed. In this case, the average unit training time was 17.6 weeks with more than 50% of all units completing training by week 32 of FY 2000. Upon examination of the nine critical resources required throughout the training cycle for this alternative, it was determined that in week 23, 20 aerial gunnery ranges would be required. This is not surprising since there will be 20 units undergoing AQC[7] at this time.

From an examination of Figure 25, it was noticed that only seven units were attending AQC during week 24. These seven units also contributed to the gunnery conflict in week 23. Thus the scheduled start times of the units with conflicts over aerial gunnery ranges were shifted, as illustrated in Figure 26, so that there was a more uniform number of units attending AQC[8] during this time frame, thereby reducing the number of aerial gunnery ranges required in week 23 to 14.

The remaining critical resources were examined for additional conflicts. However, it was determined that there were no substantial conflicts in critical resources demanded that could be reduced without a large increase in unit training time. Comparing the alternative before and after resource deconfliction, the average unit training time remains unchanged and the time required for 50% of the units to complete training is increased by 0.9 weeks.

Alternative 2. The second alternative is one in which all training was conducted at one central training location with Phases I and III subsumed in AQC. From an examination of Alternative 1, it was determined that the resource consumption and effectiveness degradation had sufficient magnitude to convince the research team that in no case would training be effective or efficient unless Phases I and III were subsumed in AQC. Thus, the remaining alternatives developed assume that individual and crew and gunnery training will be performed during AQC. In this case, the average unit training time was 17.7 weeks

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[7]AQC is identified by the letter "N" in Figure 26.

[8]AQC is identified by the letter "N" in Figure 27.

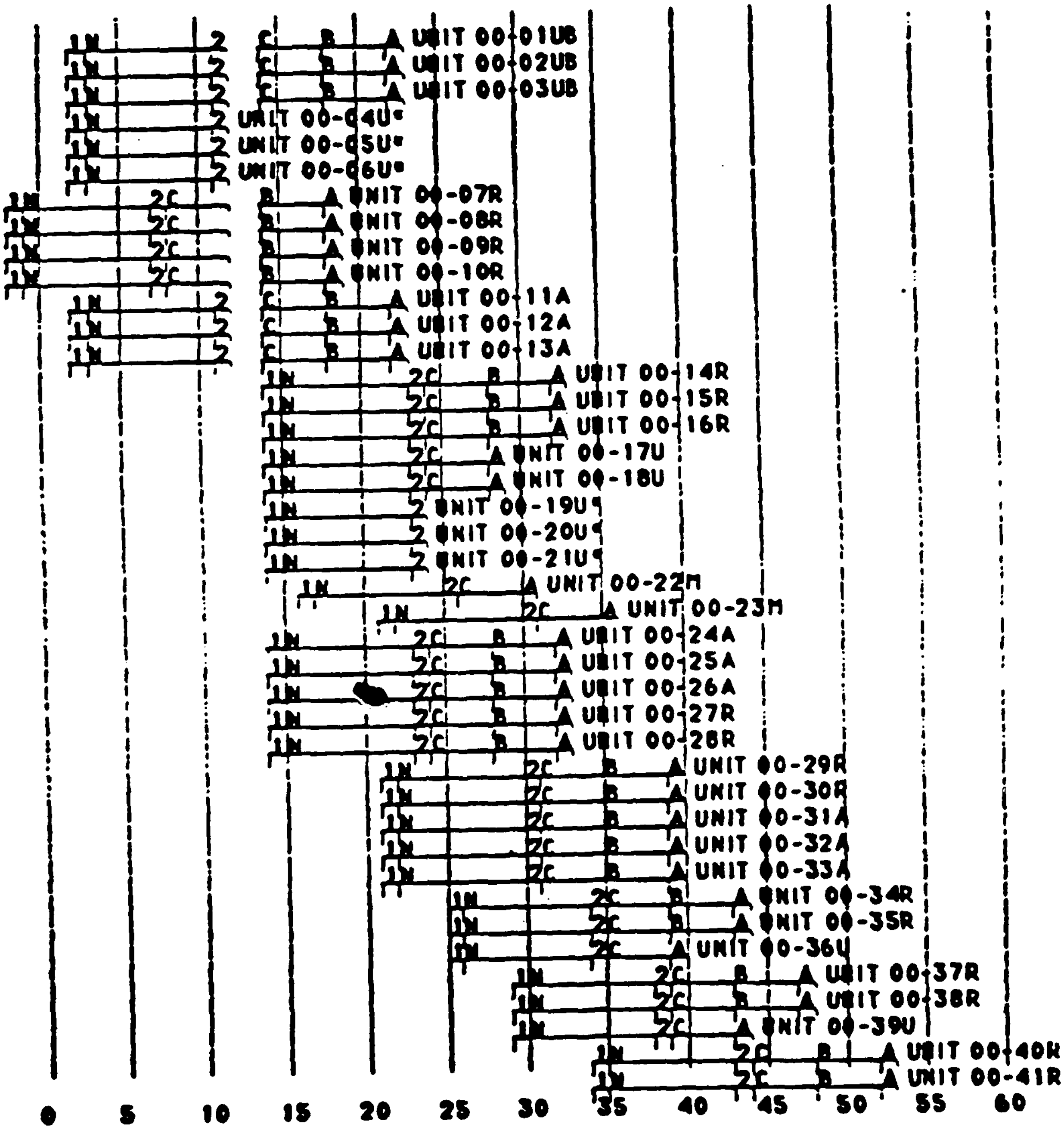

Figure 25. Alternative 1 prior to deconfliction analyses.

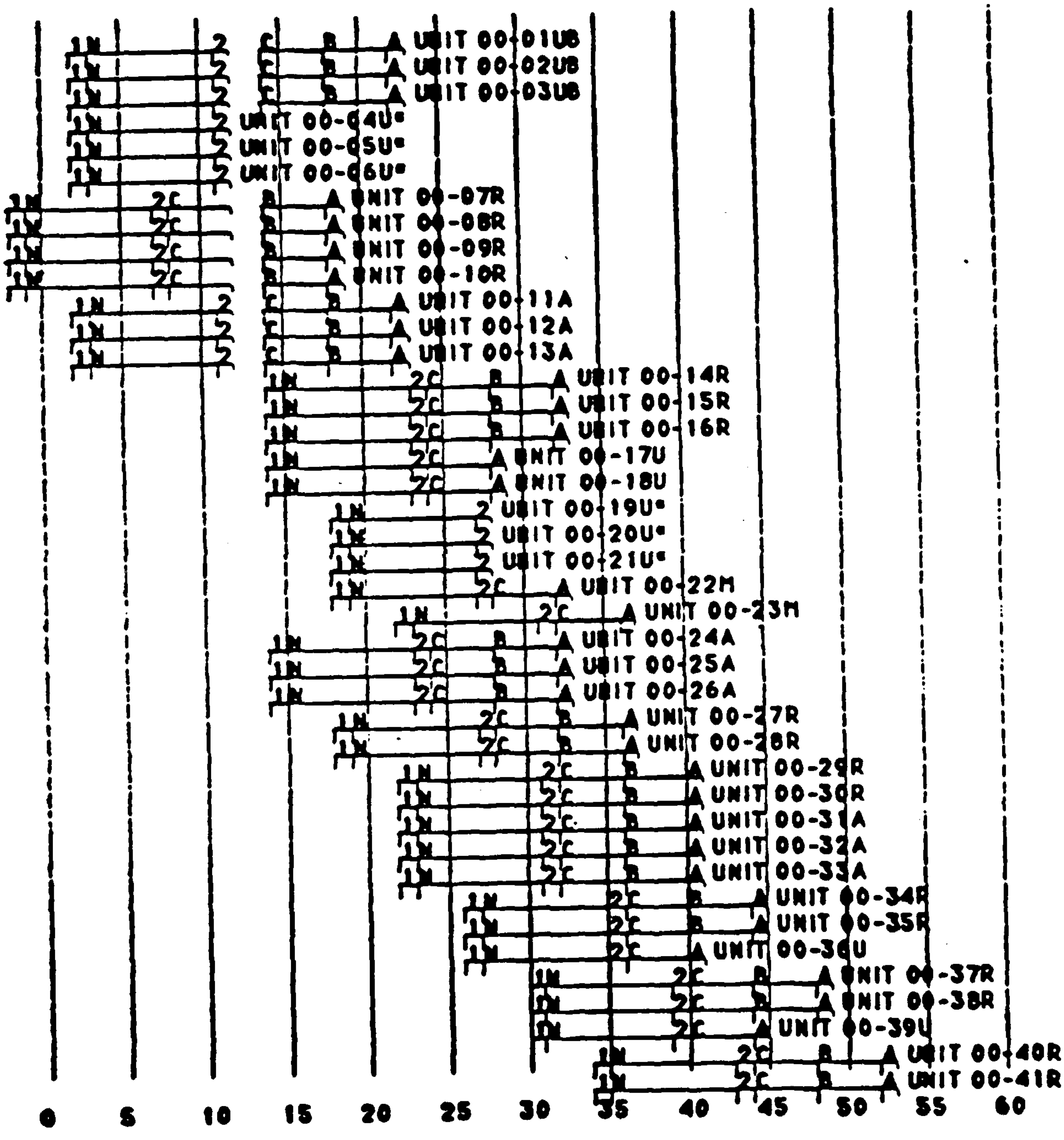

Figure 26. Alternative 1 after deconfliction analyses.

and the time required for 50% of the units to complete training is 31.3 weeks. Upon examining the distribution of the nine critical resources, it was determined that in weeks 4-7, there was a requirement for 16 aerial gunnery ranges whereas a maximum of 12 ranges was required during the remaining weeks. Additionally, it was determined that in weeks 14-18, a total of 13 maneuver areas were required whereas most training requiring maneuver areas requires less than 10 maneuver areas at any one time.

In an attempt to balance better the number of maneuver areas and aerial gunnery ranges required, it was determined that the requirement for aerial gunnery ranges only occurred when units were undergoing AQC, and that the requirement for maneuver areas occurred when units were undergoing company, battalion, or ARTEP training. Thus, when deconfliction analyses were performed by rescheduling the number of units undergoing AQC and thereby reducing the number of aerial gunnery ranges required, the number of units performing company-level, battalion-level, or ARTEP training increased. The increase in the number of units undergoing company, battalion, or ARTEP training also increased the number of maneuver areas required. Likewise, attempting to reduce the amount of maneuver areas required by rescheduling units to better balance the number of units performing company, battalion, or ARTEP training at one time resulted in an increase in the number of units undergoing AQC. Thus, a balance between the two was required. When deconflicting for aerial gunnery ranges and maneuver areas, the average unit training time was decreased to 17.6 weeks and the time required for 50% of the units to complete training was increased to 32.4 weeks. However, the trade-off of time to number of units trained provided a reduction of two maneuver areas and two aerial gunnery ranges required at any one time.

Alternative 3. The third possible alternative to conduct unit training was to conduct all training with the exception of AQC at area training centers. Before any deconfliction analyses were performed, Alternative 3 was identical to Alternative 1; the resources required are the same for each unit as when they were conducting training at their home stations. The critical resources were then examined, and the alternative was refined to reduce the number of units requiring aerial gunnery ranges during week 22 as was discussed in Alternative 1. After refining the schedule to deconflict any of the critical resources, Alternative 3, remained identical to Alternative 1.

The only resource that appeared vulnerable when training at area training centers was "garrison facilities" since in Alternative 3, units would be training away from home station throughout the training cycle. Upon examination, it was noted that in week 32, there was a requirement for 21 garrison facilities, whereas in Alternative 1, only a maximum of 14 garrison facilities were required. However, since this alternative was deconflicted in Alternative 1 to the maximum

extent possible without a large increase in training time, it was not possible to reduce the number of garrison facilities required to train units at area training centers without increasing the training time. Therefore, there was no difference in Alternative 1 and Alternative 3 in the average unit training time or in the estimated time to complete training.

Step 5 - Analysis and Comparison of Training Schedule Alternatives

Step 5 included the analysis of model outputs for each alternative, and an investigation of the feasibility of each alternative as a viable training plan. The evaluation was to include consideration of the combination of resource efficiency and program effectiveness.

Resource efficiency, as defined, could be either a subjective evaluation of the total distribution and amount of resources required or, if sufficient detailed information existed, it could entail expressing each resource in common terms such as dollars or man-hours.

Program effectiveness was outlined or measured in terms of the average time required to train a single unit, the total time required to complete the entire program, and the maximum number of units removed from the ready force structure at any one time. Consideration of the combined effect of all three measures was deemed essential. An apparent improvement in one measure could be a detriment to the overall program. For example, an alternative reducing the training time would involve a sequencing that would delay the entry of units into the program causing a delay in program completion, thereby rendering the alternative less effective. An alternative could reduce training time and speed up completion of the program, but in doing so might require an unacceptable number of units to stand down simultaneously which could adversely impact the effectiveness of the alternative.

The model applications were examined by the research team to determine the most feasible training schedule alternative in terms of total number of units trained and resource requirements for fielding the LHX. The alternative selected achieved the desired objective to schedule unit training in the most effective manner and remained within the resource constraints established by the system.

When comparing the base case and the three alternatives, it was evident that unit training for the LHX in FY 2000 would be accomplished between week 53 and week 58 where the base case required the longest time (58 weeks) to accomplish training. Alternative 1 required the least number of weeks to complete unit training for all units undergoing training in that year. The average unit training time for the base case and each alternative is summarized next.

ALTERNATIVE	AVERAGE UNIT TRAINING TIME (weeks)
Base case	22.2
Alt. 1	17.6
Alt. 2	17.6
Alt. 3	17.6

Upon examination, it was noted that there was no real difference between the three alternatives in terms of average unit training time. Additionally, the time required for 50% of the units to complete training varied only by 0.2 weeks between the three alternatives, but varied significantly between the three alternatives and the base case. The time required for 50% of the units to complete training was determined to be 35.4 weeks for the base case, whereas the time required for 50% for the units to complete training for the alternatives ranged from 32.2 to 32.4 weeks.

After examining the critical resources required for each alternative and the base case, it was determined that the resource requirements did not vary significantly between the training possibilities except in the case of aerial gunnery ranges, and maneuver areas.

In the case of aerial gunnery ranges, the base case required a maximum of 17 aerial gunnery ranges at one particular time whereas the alternatives only required a maximum of 14 aerial gunnery ranges at any one time. The base case required more aerial gunnery ranges because gunnery training, Phase III, was to be conducted at home stations. In all other alternatives, gunnery training was to be conducted during AQC. Thus, fewer aerial gunnery ranges could used for a larger number of units.

When examining the number of maneuver areas required for each of the different alternatives and the base case, it was determined that all cases required a maximum of 15 maneuver areas with the exception of Alternative 2 which only required a maximum of 11. In the case of Alternative 2, all unit training was conducted at one central training location. Thus, the total number of maneuver areas required was less because more units could occupy one maneuver area when scheduled accordingly.

Application to Displaced Equipment Training (DET)

A slightly varied approach was taken to address the individual and qualification training for the reserve units receiving equipment displaced by the LHX. Because displaced systems currently existed in the force structure, the primary difference between the base case developed for LHX units and reserve units was the requirements for units receiving displaced equipment would already be established. The method applied to the scheduling of displaced equipment units coincided with the method applied to LHX equipped units in that the four method

application steps[9] were followed. The training requirements of the systems were first identified and the model of a base case was then established. Alternatives were developed from the base case and then applied to the model to investigate the sensitivities of the various elements on the training system. Finally, an analysis was performed on the different alternatives to evaluate the effectiveness and resource efficiency of the system.

The research was limited to an investigation of individual training requirements to become qualified in the AH-1S Cobra aircraft because it required the most significant individual qualification training and provided the highest percentage of personnel to be trained when compared to the other aircraft system being displaced. A detailed discussion of the application of the prototype method to an analysis of the training schedule alternatives for displaced equipment training is provided in a report by Lindquist, Robinson and Statler (1989b).

Evaluation

The unit training research effort was successful from the standpoints of both method development and application to the LHX. The method is relatively simplistic from a conceptual standpoint and flexible enough to address a range of issues as illustrated in the applications to the fielding of the LHX as well as the displaced equipment analyses. The input required for the model is relatively straightforward and the actual operation of the model can be accomplished on readily available hardware. The model allows analysts to assess a variety of changes in training program structure or schedules rapidly.

It must be noted, however, that only a prototype version of the model was developed. While members of the LHX community at Fort Rucker found the results to be quite useful, it was beyond the scope of this research effort to develop a user-friendly version of the model. Before the model could be used in the field, some programming effort would be required to modify the user interface and output components of the computer model.

While the method is simplistic and flexible, it should be recognized that the data collection and extraction steps required to develop the input needed to exercise the model are labor intensive. The lessons learned from the analyses conducted by the research team have been incorporated in the discussion of the method to reduce the labor required in future applications as much as possible.

If users wish to apply the model during the concept development stage of a system such as the LHX, it is important to

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[9]Steps 2 - 5.

obtain consensus regarding certain training assumptions from members of the community developing the weapon system. In this effort, this was accomplished during a working conference held early in the analysis. This method allowed the research team to work much more effectively than in other efforts where this consensus on assumptions was not obtained prior to beginning data analysis.

The existing version of the unit training model is focused on unit training and does not address individual, institutional training schedules. A parallel model could be developed or an additional component added to the existing model to extend analyses to this level. The research team concluded that this extension of the model would be easy to accomplish from a conceptual and programming standpoint. However, the generation of appropriate input data for estimating institutional training resource requirements may be difficult to accomplish in the earliest phases of a system acquisition program such as the LHX. While reliable data might be lacking, the institutional training model would allow the user to assess the impact of assumptions about resource requirements or training schedules.

Perhaps the most important lesson learned from the unit training research effort is that it is very feasible to conduct useful, early training analyses with a relatively simple method. The modeling and analytic work required to obtain useful results are minimal. The principal challenge lies in applying the effort to collect and extract the data required for input into the analyses systematically.

Analysis of Life Cycle Contractor-Delivered Training for Military Aircrew and Aircraft Maintainers

Introduction

Training represents a substantial portion of the total cost in the life cycle of a major weapon system. Traditional military training for aircrews and maintainers represents a labor intensive task requiring the assignment of substantial numbers of pilots to training units rather than operational units. As part of its planning for the LHX program, the Army considered procuring life cycle contractor-delivered training (LCCDT) for LHX operators and maintainers. The research effort described in this section of the report was undertaken to increase the Army's knowledge of LCCDT and to apply this knowledge to analyses of alternative methods of conducting LHX training.

The research conducted in this portion of the LHX MANPRINT Research Program involved the collection and analysis of sensitive information which cannot be disclosed as long as the LHX procurement is active. For this reason, only a brief summary of the method and significant accomplishments of the LCCDT research effort is presented in this report. A detailed description of the research is reported in Criswell, Fineberg,

Peters, Frederickson, and Hintze (1989). The Criswell et al. report is available for limited distribution only to U.S. Government Agencies and their contractors.

Research Objectives

The LCCDT research effort represented the first in-depth analysis of LCCDT undertaken by the U.S. Army. The goals of the LCCDT research effort were very similar to those of the EAM effort: to examine the state-of-the-art and to apply the general knowledge gained in that phase of the effort to an analysis of the LHX. The LCCDT effort had four specific objectives:

1. Development of a description of LCCDT;

2. Evaluation of the cost and manpower requirements for government versus contractor-delivered training;

3. Development of concepts and criteria for evaluation of contractor proposals for life cycle training; and

4. Development of recommendations for the design of LCCDT programs to maximize the benefits of such training.

Research Overview

In order to accomplish the four objectives listed above, the LCCDT research effort was structured in three tasks. Brief descriptions of all three tasks are provided below with a more detailed discussion of the research approach to each task provided in later paragraphs.

Task 1 was focused on the development of a description of LCCDT. The description was based on quantitative and qualitative information collected on contractor-delivered aviation training programs conducted in the Army, Navy, and Air Force. The description developed through this research was used to identify critical dimensions or components of LCCDT which could be used for comparative and evaluative analyses.

Task 2 was focused on the comparison of costs for government versus contractor-delivered training. This task was further divided into two major phases. The first phase consisted of collecting cost data on traditional military training versus contractor-delivered training programs. This phase of Task 2 was conducted simultaneously with Task 1. The second phase of Task 2 involved the development and costing of strawman LHX aircrew and maintainer training programs. Once the strawman training programs were developed, the costs for delivery by both the military and contractors was computed and compared.

The third and final task in the LCCDT research effort was concerned with evaluation criteria for LCCDT proposals. This task began with a critical review of the LHX FSD RFP as well as

other aircraft RFPs. Based on this review and subject matter expertise in program evaluation, criteria for evaluating contractor training proposals were developed. In addition to development of criteria dimensions, the research team also developed standards and recommended weights for the evaluation criteria. The final report for the research effort was prepared as the final portion of this task.

Task 1 Approach

The first step in Task 1 was to collect as much data as possible related to traditional and contractor-delivered aviation training in the U.S. Armed services. The data collection efforts were focused on training which was most directly relevant to LHX training to ensure that the evaluation could be conducted within the scope and period of performance of this project. As such, Army aviation training programs received the greatest effort followed by the Air Force and then Navy training programs.

Data on the training programs were collected through document review and structured interviews with individuals knowledgeable about the most relevant training programs identified. The documents reviewed included relevant training program RFPs as well as internal Army and Air Force documents expressing official positions of various organizations regarding LCCDT and data on the cost effectiveness of such programs. Telephonic or face-to-face interviews were conducted with approximately 60 individuals. The structured interviews included questions related to the history of the training program; content of courses in the program; similarity of the aircraft to commercial aircraft; perceived benefits and drawbacks of contractor training versus military instructors, of locating training at contractor versus government facilities, and government versus contractor ownership of training materials.

The data were first organized and analyzed to determine the types of aviation training programs which have included at least some use of contractor-delivered training. The types of training examined included:

- Initial Cadre or Instructor and Key Personnel
- Initial Entry Aircrew
- Advanced Systems Aircrew

    Development of the Program of Instruction (POI)
    Deliver Classroom POI
    Deliver Simulator Instruction
    Deliver In-Flight Instruction

- Maintenance and Support Personnel

Following an analysis of the extent to which various types of training had been previously developed or delivered by contractors, the research team then analyzed the data collected from the interviews and document reviews with regard to potential drawbacks and benefits of contractor involvement in different types and phases of aviation training. This analysis was qualitative in nature.

Task 2 Approach

The approach to conducting the cost comparison between government versus contractor-delivered training can be broken into several distinct subtasks. The first subtask was to collect data regarding previous cost comparison studies. This data was collected from informal working papers and documents provided by interviewees contacted in Task 1 and review of formal documents identified in a literature search. Only one formal document on cost-comparisons for government versus contractor-delivered training was identified through the literature search.

The bulk of the effort in Task 2 was focused on the comparison of costs for government versus contractor-delivered options for strawman LHX training programs. The approach to this subtask included five steps:

1. Establishing assumptions about the boundaries of the training plan to be costed for government and contractor-delivered options;

2. Outlining operator and maintainer training courses to be costed;

3. Listing elements of the training program to be costed;

4. Pricing the cost elements for government and contractor options; and

5. Comparing government and contractor costs.

The cost comparison began with the development of certain assumptions regarding the nature of the training and the purpose of the analyses. These assumptions were made in the accordance with Forces Command, TRADOC, USAAVNC, USAALS, and Signal Center positions regarding LHX contractor-delivered training. The decision was made to focus only on costs of training implementation not training development. The period of training implementation used as the baseline for the cost comparison in the analysis was the projected 15 years of LHX phase-in beginning in 1995. Furthermore, the decision was made to examine strawman training programs for both LHX aircrew and LHX maintainers.

Once the basic assumptions regarding the nature of the strawman LHX training programs to be compared had been determined, the next step was to outline the strawman training

programs. Information in the strawman training program outlines included: courses in the programs; course components of required training devices; number of instructors; and number of students. While the attempt was made to develop training program outlines as accurately as possible, it was recognized that the exact nature of training required for the LHX could not be determined at the time of this effort. An important factor to be considered is that the most critical factor in the analyses conducted in the present effort was not the precision of the "bottom line" cost projections but the validity of methods used to generate and compare government versus contractor costs. The training program outlines were developed based on guidance from TRADOC and the LHX PM.

When the training program outlines were developed and approved, the research team identified critical training elements which would be costed for both government and contractor options.

Once the cost elements were identified, the research team collected or derived the appropriate cost data for government and contractor options. ARI provided the research team with all required government labor costs for both military and civilian personnel. Contractor labor costs were derived from a Naval Training Systems Center (1986) document. The U.S. Army Project Manager for Training Devices provided information required to cost training devices and equipment.

When the individual training elements were costed for government and contractor options, the data were summarized and comparisons for the two options were calculated. The cost comparisons were relatively complex in nature and included factors such as projected savings in personnel cost for the government due to reductions in government personnel required when training was delivered by contractors.

Task 3 Approach

The approach to developing contractor training proposal evaluation criteria was relatively straightforward. The first step in the approach to Task 3 was a review of the body of knowledge existing on program evaluation. The focus of this review was on the development of criterion measures to be used in the evaluation process. The second step was the development of a thorough understanding of the context in which the evaluation criteria would be applied. This step was accomplished through an intensive evaluation of the draft LHX FSD RFP and discussions with representatives from the LHX PM office. Based on the findings from these first two steps and analyses completed in Tasks 1 and 2, the research team developed a set of criteria which could be used in the evaluation of contractor training proposals. The criteria were organized in six generic evaluation categories and could be adapted to other major procurements as well as applied to the LHX. Once the criteria categories were identified, the research team developed standards and recommended

weights for each criterion. The final criteria with procedures for their use were compiled in a proposal evaluator handbook.

Research Results

Description of LCCDT. LCCDT programs differ from other contractor training programs (i.e., new equipment training, factory training including staff planner courses, development test and operational test training of government evaluators, initial cadre or instructor and key personnel training) in that the purpose of LCCDT is to replace military instructors, not to train them. LCCDT includes both design and development of training materials as well as training implementation over the life cycle.

LCCDT design and development programs can differ from each other in the following ways: (1) development of POIs and courseware, government or contractor, and (2) training device design, government or contractor. LCCDT implementation programs can differ from each other in the following ways: (1) instructors, government or contractor; (2) training materials ownership, government or contractor; (3) training site, government or contractor; (4) training management, government or contractor; and (5) single versus separate contracts for training and weapon system.

Cost comparison of government versus contractor-delivered training. Government and contractor dollar costs were compared in two ways. First, costs of contractor-designed training were compared to costs of the military training replaced. Cost differences obtained using this method were related to differences in training design. In the second approach, strawman LHX training programs were designed and costed using both government and contractor pricing schemes. Cost differences obtained using this method were related to differences in unit costs.

Contractor-delivered training proposal evaluation criteria. Prior to this report, the Army had no hard guidelines or criteria as to how contractor-delivered training proposals should be evaluated. Six categories of criteria were identified as being needed to conduct a comprehensive evaluation of contractor-delivered training proposals. These categories were: adequacy of instructional features, training management, personnel qualifications, corporate capabilities, personnel requirements, and dollar costs. A training proposal evaluator handbook and a RFP sample Section M, "Evaluation Factors for Award," incorporated these criteria and provided the government guidelines for the evaluation of both traditional and LCCDT or modified LCCDT LHX full scale development training proposals.

Recommendations for contractor-delivered training programs. The following approaches will maximize the benefits of contractor-delivered training programs: (1) contractor design

and development of the training system, but with government monitoring; (2) use of only experienced instructors by the contractor; (3) contractor training materials ownership, but technical data package available for breakout of expensive components; (4) use of government sites for high density training, contractor sites for low density training; (5) use of experienced contractor training program management and a lean but experienced government oversight team; and (6) weapon system and training system development in a single contract. The LHX acquisition strategy permits implementation of all of these recommendations except contractor training device ownership.

To minimize LCCDT costs, the government should ensure that the contractor: (1) employs permanent area residents and is not allowed to pay special assignment bonus, travel, and per diem incentives; and (2) keeps contractor-provided office space to a minimum.

Evaluation

The research effort on LCCDT was successful in accomplishing the research objectives identified at the beginning of the research. The effort further demonstrated the capability to conduct early training analyses for new weapon systems. It must be noted, however, that analyses conducted during the concept development phase of a system such as the LHX require development of a set of reference assumptions and will provide results which are most appropriately used in a comparative rather than absolute manner. In other words, the analyses may provide information that is useful in comparing training alternatives, but some caution must be observed in using the analyses conducted at this stage to project the final levels of resource requirements or training costs.

In addition to providing further evidence of the feasibility of conducting MANPRINT analyses, this research effort provided data that was considered very useful by decision makers in the LHX community. Beyond the data generated by the analyses, the research effort provided other products such as the handbook for evaluating contractor training proposals.

One of the principal goals of this research effort was the development of a description of LCCDT. The effort was successful in providing the first comprehensive description and analysis of LCCDT. The comprehensive view of LCCDT developed during the early stages of the project were critical in guiding the analyses conducted in later tasks.

It is interesting to note that neither the conceptual work nor the analyses conducted during the research effort required or resulted in major methodological breakthroughs. Rather, the research team was able to accomplish its goals by systematically applying existing analytic methods. The ability to conduct the required analyses with existing methods is a finding which has

been replicated a number of times in subsequent MANPRINT research conducted with the Forward Area Air Defense System (FAADS). The critical lesson to be learned is successful MANPRINT analyses require a comprehensive framework and understanding of the objectives of the MANPRINT program and the materiel system under analysis. Given these elements, existing methods can often be adapted or applied in their existing form to conduct the required analyses.

LHX MANPRINT Integration

Introduction

The LHX MANPRINT Integration research project was initiated early in the LHX MANPRINT research program. The purpose of this effort was to develop a method that integrated the results of the various processes and methods addressing MANPRINT program areas. The result of the integration was intended to be a MANPRINT assessment package compiled on a timetable that permitted interaction with the technical hardware design. The Milestone I and II ASARC decision briefing was chosen as the first point at which a complete MANPRINT summary would be formulated.

The goal of the research effort was to develop a generic method or framework for integrating MANPRINT information. The intention was to use the LHX acquisition program as a sample program for developing the method with the package prepared for the LHX ASARC serving as a prototype product. The products reported in this document were not presented in the briefing as planned because the ASARC did not occur within the period of performance of the research effort. Also, because the LHX acquisition process was still in its early stages, only a preliminary framework for full organization of MANPRINT information was developed. The remainder of this section describes the objectives, approach, and components of this framework.

A detailed discussion of this integration effort is provided in an ARI working paper by Lindquist, Statler and Welp (1988).

Research Objectives

When this project was conceived, there was no method for the management of MANPRINT information nor was there consensus among decision makers in the Army as to the content and format of information needed to conduct a thorough MANPRINT assessment. Therefore, the objectives of this effort were to:

- determine what information was pertinent,
- develop a method to manage the information, and
- consolidate the information into a MANPRINT assessment package in preparation for ASARC.

Research Approach

Conceptual Framework. The accomplishment of the objectives of the research effort required a conceptual framework or model of MANPRINT to provide the basis for evaluating the relevancy of MANPRINT-related information.

The framework utilized focused the attention of the research team on two primary concepts, system operability and system supportability. The research team decided that these two concepts provided the basis for organizing information from the six MANPRINT domains into "higher order" issues.

Three major characteristics of MANPRINT-related information required for an affirmative decision from the ASARC served to unify the direction of the effort. Those characteristics were the ability to: (1) demonstrate that the system was operable; (2) demonstrate that the system was supportable; and (3) express the operability and supportability by quantifying the requirements of each MANPRINT domain and the degree to which fulfillment of the requirement could be assured.

It was determined that the information, when consolidated, should accurately indicate whether a system was operable and supportable, and if not, if corrective action could be taken prior to ASARC. The concept presented at Milestone I/II had to appear to be feasible within the established risk parameters. Therefore, the ability to provide evidence that a domain was operable and supportable became the criteria for identifying possible issues that should be resolved prior to Milestone I/II. The third characteristic, quantification, was based on the conclusion that the most convincing evidence of attainment of a resource capability was the comparison of a numerically defined requirement with the projected outcome of a plan or approach.

For the purposes of this analysis, operability was defined as the capability of all personnel affected by the system to perform all of their system-related tasks successfully to a standard sufficient to enable the accomplishment of the mission and thereby effectively neutralize the threat without exposing any personnel to unacceptable risks. Therefore, operability was dependent on the MANPRINT domains as they pertain to the tactical, garrison, or training environment.

Supportability in this context was defined as the ability to recruit, train, and sustain those individuals in the force necessary to attain and maintain operability. Supportability, therefore, was dependent upon the remaining MANPRINT domains of manpower (numbers of individuals of specific descriptions); personnel (descriptors and management policy and procedures relating to individuals throughout their tenure in the Army); and training. Again, this was an all encompassing criteria in that it pertained to the entire spectrum of events and activities relative to the weapon system, not just its tactical employment.

Operability and supportability were operationalized by two questions. The first was, can this soldier operate this machine with this training? Second, can the soldier and the training be made available? The problem then was to define the soldier, the machine (to include interface characteristics), and the training required. The apparent simplicity of the question belied the complexity of the problem. An appropriate comparison might be Chinese boxes nested one inside the other. Every element has many sub-elements within it and the answer to every question seems to pose another question. For example, if the answer to enabling the soldier to accomplish a series of missions is to automate tasks, the addition of the automated hardware poses its own series of MANPRINT questions. In the case of aviation and aviation support, the presence of computer operations and support personnel was limited. The inherent complexities of fielding such a highly automated new weapon made it necessary to establish a systematic approach to assess system operability and supportability.

The third characteristic, quantification of the domain, established the research goal. Ideally, each domain should be expressed in numerical terms that describe the requirement and the total systems response to the requirement. Table 13 provides examples of the terms in which the final status of each domain might be expressed.

The method used was an iterative process resulting in a topical outline that evolved from a review of acquisition documents. The six MANPRINT domains provided the basis for the development of the outline. Documents were reviewed to extract pertinent information addressing the questions of system operability and supportability for each domain. As the acquisition documents were reviewed and through conversations with members of the acquisition community, the research team was able to expand and define the outline to include subdivisions for each of the six domains. For example, the domain Human Factors was subdivided to address system operability and supportability for the areas of Human Characteristics, Anthropometric Data, System Interface Requirements, and Human Performance. A complete outline structure is presented in Table 14.

Once the outline was developed an exhaustive research effort was undertaken to quantify each of the domains as completely as possible. That effort included a more detailed literature search with a review of the documents listed in Appendix B as well as participation in numerous meetings and briefings held by the various members of the acquisition community.

Evaluation

The method developed in this research effort represents a general structure for organizing MANPRINT information and specific prototype modeling technologies for assessing manpower requirements and effects in a system acquisition and fielding

Table 13

Quantification of MANPRINT Domains

Manpower	Required strengths Manpower authorization criteria Basis of issue
Personnel	Recruiting rates Re-enlistment rates Attrition rates Promotion rates Trainees, transients, holdees and students time Education level
Training	Number of courses Course lengths Instructor ratios Equipment ratios
Human Factors	Aptitudes Height Weight Medical profile Vision acuity Reaction time
Health Hazards	Dose rates Mortality rates Morbidity rates
Safety	Accident rates Exposure rates and times Lost time rates

Table 14

Outline Structure

I. HUMAN FACTORS

a. Human Characteristics
   1. Operators
   2. Maintainers
b. Anthropometric Data
   1. Operators
   2. Maintainers

Table 14 (Continued)

Outline Structure

- c. System Interface Requirements
  - 1. Operators
  - 2. Maintainers
- d. Human Performance
  - 1. Operators
  - 2. Maintainers

II. Health Hazards

- A. Operators
- B. Maintainers

III. Safety

- A. Operators
- B. Maintainers

IV. Personnel

- A. Aptitudes Required
  - 1. Operators
  - 2. Maintainers
- B. Experience Required
  - 1. Operators
  - 2. Maintainers
- C. Recruiting
  - 1. Operators
  - 2. Maintainers
- D. Training
  - 1. Operators
  - 2. Maintainers
- E. Personnel Assignment
  - 1. Operators
  - 2. Maintainers

V. Training

- A. Training Effort and Cost
- B. Training Times
- C. Program Development Appropriate To Aptitudes
- D. New Equipment Training
- E. Qualification Training During the Phase
- F. Officer, Warrant Officer and NCO Development Training
- G. Unit Training
- H. Devices in Tactical Units

VI. Manpower

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process. The research team initially hoped to develop a computer-based decision method to aid decision makers in structuring and analyzing all MANPRINT information. However, after working on this effort for several months, the team concluded that the unique characteristics of each system acquisition program precluded the development of more than a general structure to guide data collection efforts and that integration of all components in detail was beyond the capability of this effort. The research effort therefore, focused on the manpower domain and did produce the prototype LHX MANPRINT manpower assessment and prediction models outlined in this report. To develop a complete MANPRINT assessment package and to evaluate the utility of a structure for organizing all MANPRINT information would require the time and resources to follow an acquisition through completion. For these reasons, the research team was unable to achieve its initial goals of developing a complete, prototype MANPRINT assessment package or fully evaluating the utility of the method developed. As the LHX acquisition process progresses, the utility and applicability of the products developed so far will be measured and assessed.

Evaluation of the LHX MANPRINT Research Program and Lessons Learned for Future MANPRINT Research Applications

Introduction

In each of the sections of this report, specific research efforts conducted in the LHX MANPRINT program are examined in terms of the research goals for that effort. This section reviews the full process and provides an overall evaluation of the LHX MANPRINT research program. There are three primary criteria which were used in this evaluation. The three criteria include:

1. MANPRINT method development

2. Contribution to LHX decision making, and

3. Increased acceptance of MANPRINT analyses

The first of the three criteria listed above, MANPRINT method development, is probably of greatest interest and importance to the intended audience of the current report. This criteria is most directly relevant to the evaluation of the success of the LHX program from a research perspective. The critical issue related to this criteria is whether or not the program resulted in any major methodological breakthroughs which could be used in future MANPRINT research.

The second criterion, contribution to LHX decision making, reflects the applied nature of the LHX research program. It would be inappropriate to evaluate the LHX MANPRINT research program without examining its success in meeting the goals and

pressures which existed to conduct a MANPRINT research program that would provide useful data directly to the LHX community.

The final criterion listed above, increasing the acceptance of MANPRINT analyses, is a criterion which would be of less importance in a basic research program. Given the applied nature of the LHX MANPRINT research program, however, it is a criterion which must be applied in evaluating the effort. This final criterion is also the most difficult to evaluate in an objective manner.

Development of MANPRINT Methods

From a methodological standpoint, the overall LHX MANPRINT research program was successful in breaking new ground. The approach provided a preliminary framework for guiding the development of a comprehensive MANPRINT analysis program for major system acquisition efforts. The approach initially developed during the LHX MANPRINT research program, has been successfully applied and refined in the FAADS MANPRINT research program.

The MANCAP model which has evolved from the LHX organizational modeling efforts has great potential as a valuable tool which can be applied to examine manpower requirements in new materiel systems. Most importantly, the model can be applied early in the concept development phase and serve as a means by which system designers and program managers can generate and evaluate a variety of design alternatives. The model can be used to examine changes in maintenance organizational structures and proposed mission profiles as well as changes in the system's RAM characteristics. Furthermore, the model allows the decision makers to examine MANPRINT impacts beyond that of a single system in isolation. Manpower requirements and system performance can be examined in the context of a unit attempting to perform a specified mission. Thus, the model can be of use to "MANPRINT doctrine" as well as the materiel system itself.

The method developed during the unit training effort also has the potential of wide applicability. While the computer model used in the unit training project was never developed beyond an early prototype stage, it was successful in generating data considered useful by the Aviation School. The general training planning method and the computer model, if fully developed, have considerable potential in aiding in the planning of training during the fielding of new systems as well as reserve component unit training.

Other methods and computer models developed during the LHX MANPRINT research program, such as the model used in the EAM research effort, have more limited direct applications to other system acquisition efforts. These models were used to answer LHX specific questions and were never developed beyond the prototype stage. While the models themselves cannot be directly applied,

the general approaches developed in these analyses are highly relevant to solving similar problems in future system acquisition programs.

In addition to the actual models and methods developed during the LHX MANPRINT research program, there are a number of "lessons learned" that are relevant to future work in the development of MANPRINT methods. The last section of the technical report presents an overview of some of the most relevant insights or lessons learned by the research team conducting the LHX MANPRINT research program.

Contributions to LHX Decisions Making

Throughout the LHX MANPRINT research program, the HTI research team maintained considerable contact with members of the LHX PMO, the Aviation School, and other organizations active in the LHX program. The contact included delivering formal briefings, participating in work group meetings, and providing written answers and reports in response to general and specific MANPRINT issues raised by various members of the LHX community as well as providing results from the programmed research. The LHX MANPRINT research team provided the ILS manager of the LHX PMO with continued analytic support and a series of briefings on projected maintenance manpower requirements. The results of the analyses were used by the LHX PMO to estimate overall LHX manpower requirements and costs. In addition to the manpower estimates, the research team provided data to the Aviation School regarding alternative unit training programs and related training resource requirements. Feedback from the school indicated that this information was considered very useful.

While it is possible to identify the information provided and the users who received information generated by the LHX research program, it is more difficult to assess the extent to which this information influenced decisions concerning the LHX. The entire LHX acquisition program has undergone considerable change during the course of the LHX MANPRINT research effort and a number of the decisions for which the findings of the LHX MANPRINT research program have greatest relevance have yet to be resolved. The results generated by analyses conducted under the LHX MANPRINT research effort, however, have been briefed to key Army decision makers involved in the LHX program and the team feels that the LHX MANPRINT analyses will provide valid and usable lessons to aid in other major system acquisition decisions-related MANPRINT analyses. For example, current applications to the FAADS program suggests that results from such analyses may be useful in critical acquisition decisions. The results of MANPRINT data collection and analyses has been carefully considered in making selections of the winning systems for the initial components of the FAADS.

Increased Acceptance of MANPRINT Analyses

Throughout the course of the LHX MANPRINT research effort, the research team experienced varying degrees of acceptance of a MANPRINT process from members of the LHX community. Overall, the teams assessment was that the program resulted in increased acceptance of MANPRINT and improved recognition of the value of conducting such analyses. As will be noted below, the manner in which the methods were developed and applied is related to the degree of acceptance. Probably the greatest increase in acceptance of MANPRINT analyses occurred when the research team provided the ILS manager of the LHX PMO with a demonstration of how the computer models developed under the LHX MANPRINT effort could be used to generate and evaluate quickly changes in manpower projections resulting from changes in LHX RAM specifications. Increased acceptance of the results of MANPRINT analyses was also gained from the Aviation school when they were actively involved in establishing the parameters for various assumptions in the unit training research effort.

Other portions of the LHX research program such as the 2LM effort and the earliest phases of the organizational modeling effort were less successful in improving acceptance of MANPRINT analyses. In these efforts, the involvement of the end users in development of the methods was less carefully structured and the processes used to generate the MANPRINT results were not as well understood by the LHX community.

Key distinguishing features in these portions of the LHX MANPRINT research program that increased user acceptance and those which did not, were the timing and nature of end user involvement. Those portions which seemed to promote user interest and acceptance were characterized by early and continued user involvement in the development of the methods. For example, in both the unit training and MANCAP modeling efforts, members of the LHX community provided input as to the nature of the assumptions to be included in the design of the models. Furthermore, the users were actively involved in "work group" type of meetings to provide input rather than passively receiving formal briefings. Such user involvement has also been characteristic of the highly successful FAADS MANPRINT research program.

MANPRINT Method Lessons Learned

The LHX MANPRINT research team experienced a wide range of successes and failures throughout the course of the effort. Perhaps the most important lesson learned from this experience is that it was possible to develop and implement MANPRINT analysis methods which provide information considered useful by the user community.

Presented below are additional lessons learned that the research team believes are highly relevant to the design and

implementation of successful MANPRINT research efforts in the future. Many of these lessons learned have been confirmed through additional experience gained in the design and execution of the MANPRINT research program supporting the FAADS. The lessons learned are fairly general in nature. More specific lessons learned derived from individual LHX research programs are presented in individual sections of this report. The information presented below has been selected primarily because of its relevance to future MANPRINT efforts regardless of the nature of the specific system being evaluated.

User involvement. The importance of user involvement and development of methods incorporating a user perspective was repeatedly underscored throughout the LHX MANPRINT program and again in the FAADS effort. While it may seem trite to stress the importance of involving the end user in development of MANPRINT methods, our experience suggests that this goal is not effectively achieved in most research efforts. Often this occurs because there are multiple consumers of the information provided by MANPRINT analyses and these consumers have different objectives and requirements. If the research team focuses its attention on only one segment of the user community such as the TRADOC representatives, the methods developed will often fail to incorporate variables or assumptions relevant to other members of the system acquisition community. As a result, the methods will fail to provide the information considered essential by key users of the MANPRINT data or will provided information considered irrelevant because of the assumptions used in the analyses.

An essential lesson learned regarding user perspective and user involvement is that a thorough contextual analysis must be conducted to identify all key players and their requirements. This analysis must be conducted up-front before beginning the design of the research method and must identify factors such as manpower and time constraints existing in the user environment as well as the information requirements and organizational biases of the key users or consumers of the method and results produced by analyses using the method.

Timeliness of Research. A critical lesson learned from portions of the LHX MANPRINT research program such as the 2LM effort, is the need to provide results in a timely manner. Often, the researcher is reluctant to provide tentative results from prototype analyses because the data must be qualified by a number of disclaimers or because he or she believes the method provides only a "70% solution." This lesson is closely related to that of understanding the nature of the user's environment. As a general rule, we have found that the user often requires a "70% solution" within a short period of time rather that waiting for a validated "99% solution" that requires years of development.

The user is often faced with decisions and funding deadlines which cannot be postponed. Under these conditions, a "70%

solution" derived from systematic analyses of even a protypical nature are preferable to making a decision with little or no analytic results. The responsibility of the researcher is to clearly indicate the nature of the limitations of the results provided by such prototype analyses and to work with the user in preventing clearly inappropriate interpretations of the data.

Value of Rapid Prototyping. The use of rapid prototyping in the development of analytic methods and computer models is a technique which proved to be very effective in the LHX MANPRINT research effort. The research team learned that construction of prototype models early in the method development process provided a means to obtain meaningful user involvement and protected against the long-term investment of time and energy in pursuit of "dead-end" methods. The development of a working prototype model with limited application provides a vehicle through which the research team can demonstrate concepts and obtain feedback from the end user community. While such a model may provide only limited results, the demonstration of the principles and processes to be incorporated in the final model provided an excellent means of identifying major flaws in logic, omission of critical modeling dimensions, requirements for input data, and acceptability of output formats.

Underestimation of Data Collection Requirements. An error made in several of the earliest LHX MANPRINT research efforts was to underestimate the time required to obtain and format input data needed to conduct MANPRINT analyses. A conservative estimate is that 50% of the entire labor expended on the LHX research program was devoted to data collection, data scrubbing, and development of structured databases. The lesson learned is that much of the data required as input into analytic models does not exist or can be obtained only through labor intensive efforts. Often, input values required for analyses had to be generated through a process of building consensus on the range of values to be used as assumptions in development of a base case for analysis. This problem will be particularly acute in the development and application of MANPRINT methods for acquisition programs which are early in the concept development phase such as the LHX.

In the later phases of the LHX MANPRINT program, the research team budgeted considerable percentages of total hours expended for the data collection and database development tasks related to MANPRINT analyses. This perspective proved to be very realistic in projects for which the research team had not previously developed databases.

Sensitivity of Method to Appropriate MPT Factors. One of the most important lessons learned in the course of the LHX MANPRINT research program was the need for the development of a second generation of MANPRINT methods that are sensitive to MPT factors above the single system level. This lesson was driven home in attempts to examine the 2LM concept and the extension of

the organizational modeling effort to the division level. Both of these research efforts illustrated the need for MANPRINT methods which were sensitive to organizational structure and doctrinal factors in addition to system design specifications and individual operator and maintainer characteristics.

While "single system" analytic methods can be used to generate estimates in the analysis of organizational MANPRINT issues, careful evaluation of the results produced will reveal serious problems. The estimates produced by these methods will be the result of input data on system design specifications and individual operator or maintainer data, but will not directly reflect changes in organizational structure or doctrine and operating procedures which influence crew or unit level performance factors. Furthermore, the problems will not be readily apparent unless the research team makes extensive critical comparisons of alternatives that differ on organizational structure or tactical doctrinal dimensions. Simple comparisons of different weapon system designs, comparisons of changes in doctrine related to individual operator or maintainer factors such as available maintenance man-hours per soldier, or evaluation of a single organization structure will not reveal the lack of sensitivity of the methods.

The lack of sensitivity of the methods to factors above the single system level must then be compensated for by making assumptions regarding how the organizational issues will impact on input values which are reflected in the method's processing and output. Often, these adjustments in input values are made using a highly subjective and non-standardized process, subject to significant bias from these unquantified variables. The incorporation of organizational level factors in the MANPRINT analysis method itself requires explicit statement of how such variables are represented. This requirement for explicit programming of the factor reduces the opportunity for both unintentional or intentional bias in the results because the processes producing such results are subject to critical review.

Performance-Oriented Modeling. One of the most important orientations developed by the research team working on the LHX MANPRINT research program, was an understanding of the need for a "bottom line" performance measure in all of the MPT analysis methods. The important lesson underlying this orientation is that comparison of MPT estimates for various system design alternatives or different organizational structures can take place only within the context of some performance criteria. The exact nature of the performance measure to be incorporated in the MANPRINT method will vary depending on the purpose of the analysis. For example, if the analysis is conducted to examine operator or maintainer manpower requirements, the performance factor might be system availability or projected capability of the unit to accomplish a range of mission profiles. If the issue under investigation is the evaluation of unit training strategies during fielding of the new system, the appropriate

performance measure might be the average time to achieve a specific level of competence or the average number of units that are not combat ready during a specified period of time.

The critical point is that some measure of performance other than MPT estimates in the analytic method be included to provide a context in which to evaluate alternatives. This analytic strategy provides the researcher with data which can be formulated into a more convincing and valid case than that from a strategy which assumes equal performance of each MPT alternative.

Value of Interdisciplinary Teams. As the LHX MANPRINT research program progressed, the research team was structured to ensure an interdisciplinary perspective. A lesson learned early in the program was that the methods and models developed by a research team reflected the conceptual and methodological biases of its developers. To ensure a balanced approach to MANPRINT analyses, a research team needs to have a balanced composition which includes personnel with engineering, operations research, behavioral science, and computer programming backgrounds. The team must also include subject matter experts with extensive knowledge of the weapons system and target organizations receiving the weapons systems under evaluation. Depending on the nature of the analytic method under development, economists, human factors engineers, or manpower analysts may also be required on the team. A key responsibility of the program manager on a major MANPRINT research effort such as the LHX is to facilitate the exchange of information and perspectives from the various members of such an interdisciplinary team.

Tradeoffs Between Speed and Ease of Use versus Precision. A critical lesson learned through the extensive contact with members of the LHX community, was that users tend to prefer fast and "easy-to-use" methods that provide relatively rough estimates versus those which may have greater precision at the cost of increased input data requirements and time. The dynamic nature of major system acquisition programs and probability of changes in system design early in the concept development phase are major factors mitigating against the need for point estimates of manpower, personnel or training requirements. Instead, the pressures exist for development of methods which provide the user with the capability to generate and evaluate rapidly alternative projections that can be compared for "order of magnitude level" MPT differences.

The development of such "what if" analyses tools are also consistent with other factors in the user environment. Often, the program management offices of major system acquisition programs have limited staff and computer equipment. Therefore, models which can be executed on microcomputers by staff members with a limited amount of training and data input requirements are likely to be used when other more precise methods would be rejected because of resource limitations. The design of methods which provide only range estimates as opposed to point estimates

is also more consistent with the quality of the data which is typically available to the user in the system acquisition environment.

Summary

The LHX MANPRINT research program was the first comprehensive attempt to develop and apply MANPRINT methods in support of a major acquisition program in the Army. The multi-faceted program was successful in breaking new ground and the research team learned a number of valuable lessons which have been transferred to the development of a highly successful MANPRINT program supporting the FAADS. Many of the insights shared in the lessons leaned above may be viewed by some readers as common sense or more closely related to program management than technical research and development. We have chosen to focus on these points, however, because experience suggests they are most important to successful implementation of a MANPRINT research program.

One final comment on the lessons learned from the LHX program is warranted. While there is considerable room for new methodological development within the MANPRINT arena, a research team with a comprehensive understanding of the basic concepts and goals underlying the MANPRINT initiative can modify and apply existing tools to help users in the acquisition community, today. The key to providing this help is to understand the needs of the end user and to provide assistance consistent with that need rather than attempting to change the user's need to match the goals of the research community.

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Appendix A

Attributes

The attributes of the system employed in the mission simulation are listed in this appendix under the headings of assumptions, semi-fixed parameters, or interactive parameters.

Assumptions

1. All individuals will begin their shift at time = 0.

2. All maintenance actions will be managed in a tub file at each level of maintenance.

3. Once an individual begins to perform a maintenance action (repairs or trouble-shooting), he will take the action to the next status before returning it to the tub file and checking his remaining time.

4. It is assumed that individuals will obtain supply parts at the lowest level possible. (i.e., parts will be requested from the PLL stock before requesting parts from the ASL stock, assuming that the aircraft is located at that level of maintenance or below).

5. The crew chief is the only individual able to take or retrieve an aircraft from higher maintenance or the field.

6. If the number of crew chiefs is less than the number of aircraft, overhead personnel will be sent to the HSC to obtain the parts needed.

7. The same MOS are available at Level 2 and Level 3 maintenance.

8. All aircraft repaired above the flight line must be checked by a technical inspector before returning to mission available status.

9. The technical inspectors, repairers at Level 2, and repairers at Level 3 do not perform any other scheduled maintenance tasks. If time on their shift permits, they perform "other common soldier tasks."

10. All repairs checked by the technical inspector will be assumed to be correct. There will be no repairs rejected by the technical inspector.

11. All aircraft are repairable.

12. All EMAs must be troubleshot.

13. The MTBMAF is used to derive the probability of an EMA during pre-flight and in-flight. All other failures will be discovered during post-flight based upon the probabilities derived from the MTBEMA.

14. A daily must be performed before an aircraft is available for its first mission of the cycle.

15. All aircraft that are not flight line repairable will be transported to Level 2 or Level 3 service.

16. There are no parts available at Level 1 service. All parts must be obtained from the Level 2 service or above.

17. All work orders are returned to the tub file after a supply part is ordered or is received before the aircraft is repaired.

18. All orders are processed according to first-in, first-out (FIFO) and priority of work category.

19. A part requirement is not a candidate for controlled substitution until all supply channels through the theater have been exhausted.

20. If an aircraft is located at the AMC for repair, an attempt is made to get the part from the AMC shop stock before requisitioning the part from the ASL.

21. If controlled substitution is available and elected to be employed, the same repairer will remove the part from the aircraft to be cannibalized.

22. All controlled substitution will be from downed aircraft located at the AMC.

23. When an aircraft is not available to be cannibalized or if there is not a float aircraft available, the only option is to wait for the part.

24. The float account will be maintained at the AMC.

<u>Semi-fixed Parameters</u>

1. Crew chiefs' duty days will coincide with the aircraft mission cycles.

2. If an individual is not available to perform a daily, a launch, a recovery, or a post-flight, the aircraft will wait for the next crew chief available to perform the maintenance action.

3. When there are no parts needed to repair the aircraft and the aircraft is flight line repairable, the crew chief will repair the aircraft at the time of troubleshooting. The work order will not be placed in the tub file.

4. The priorities in the tub file are:

   a. Recover all down aircraft.

   b. Perform all daily's.

   c. Perform all launches.

   d. Recover all aircraft from missions.

   e. Recover all aircraft from higher levels of maintenance.

   f. Substitute any floats and transport to unit.

   g. Perform EMAs.

   h. Perform other maintenance actions (assuming direct maintenance time left and not end of mission cycle).

   i. Perform other tasks (assuming time left in mission cycle).

5. EMA work orders in the tub file have four status:

   a. EMAs that have not been troubleshot.

   b. EMAs awaiting maintenance.

   c. Repairs waiting to be inspected.

   d. EMAs awaiting parts.

6. At each aircraft status update, the individual will return the work order to the tub file, check his direct maintenance time and mission cycle time remaining, and get the highest priority from the tub file.

7. The crew chief will only remain with the aircraft at higher levels of maintenance when there is at least one crew chief per aircraft.

8. The proration of maintenance above the unit is derived from the MARC using the following steps.

   a. The total number of maintenance man-hours minus the number of scheduled maintenance man-hours

equals the amount of unscheduled maintenance man-hours.

b. The number of unscheduled maintenance man-hours minus the number of maintenance man-hours of technical inspectors equals the total number of unscheduled maintenance man-hours for the repairer.

c. The total number of maintenance man-hours for the AH-1, OH-58, and LHX repairer minus the number of scheduled maintenance man-hours equals the total number of unscheduled maintenance man-hours for the aircraft repairers.

d. The probability that an aircraft is not flight line repairable multiplied by the total number of repairer maintenance man-hours to obtain the total number of maintenance man-hours at Level 2 and Level 3 service.

e. The total number of maintenance man-hours at Level 2 and Level 3 service minus the number of maintenance man-hours of the trades MOS equals the number of maintenance man-hours of the aircraft repairer at Level 2 and Level 3 service.

f. The total number of maintenance man-hours for each MOS at Level 2 and Level 3 service divided by the total maintenance man-hours at Level 2 and Level 3 service equals the percentage of workload for each MOS.

9. The rate of work for Class IX supply is equivalent to the rate of work in the LHX application. The supply requirements generated by the model are compared with the personnel workload to determine the Class IX supply manpower required for units in the division.

10. Class III and V supply is derived based upon the doctrine that two supply persons are required to refuel or rearm an aircraft and the requirement that staff planning is to be conducted based upon 100 percent aircraft availability.

11. Class V supply personnel requirements in the ATP Section of the Forward Supply Company of the Supply and Transportation Battalion for LHX units are determined based upon a standard configuration for the AH-1 to include eight TOW missiles, 38 2.75 inch folding fin aerial rockets, and one turret with 265 grenades and 4000 rounds of ammunition. Armament configurations for the OH-58 are not applicable.

12. A mission abort will occur if there are not any AH-1 to launch an attack mission.

<u>Interactive Parameters</u>

1. All repairers above the flight line will work 12-hour shifts.

2. The direct maintenance time allowed per individual is 3.4 hours per 12-hour shift.

3. The indirect maintenance time expected per individual is 2.5 hours per 12-hour shift.

4. The time required per individual to perform other tasks is 6.1 hours per shift.

5. There is no time associated with an individual going to the tub file to obtain a work order.

6. If a repairer cannot get a supply part needed from the PLL stock, he will only wait for the part if the expected time of the shortest possible maintenance action- troubleshooting and round trip travel.)

7. .5 hours will be allowed for an individual to travel to and from a higher level of maintenance in order to get a repair part.

8. The expected time to perform the actual repair of the aircraft once the parts needed are available is based upon the MTTR of which 1/4 of the time is for troubleshooting and 3/4 of the time is for repair.

9. It will take .5 hour to take an aircraft to or from a higher level of maintenance.

10. It will take 1.28 hours and .95 hours for the technical inspector to inspect repairs performed on the AH-1 and OH-58 respectively. These figures were derived in the following manner:

    <u>AH-1</u>

    MTBMAF=5.4 hours
    Amount of repairs inspected by TI=80%
    Rate of work for TI= .19 MMH/FH

    $$\frac{5.4\text{FH}}{.8\text{ failures}} \times \frac{.19\text{MMH}}{\text{FH}} = 1.28\text{ MMH/failure}$$

OH-58

MTBMAF=7.6 hours
Amount of repairs inspected by TI=80%
Rate of work for TI= .10 MMH/FH

$$\frac{7.6FH}{.8\ failures} \times \frac{.10MMH}{FH} = .95\ MMH/failure$$

11. The float account will contain two aircraft.

12. The numbers and types of MOS used in the simulation model are as follows:

MOS	AHC	HSC	RECON	HHT	HHC	AMC
66J	0	1	0	2	0	1
66N	0	1	0	0	0	4
66V	0	2	0	2	1	2
66Y	0	4	0	2	0	2
67N	0	3	0	1	0	17
67T	0	0	0	0	0	1
67V	4	9	6	3	8	10
67Y	7	16	4	8	0	12
68B	0	2	0	1	0	8
68D	0	2	0	1	0	5
68F	0	1	0	0	0	6
68G	0	3	0	2	0	5
68H	0	0	0	0	0	3
68J	0	8	0	4	0	4
68K	0	1	0	1	0	1
68M	0	7	0	2	0	4
35K	0	9	0	4	0	2
35L	0	0	0	0	0	4
35M	0	0	0	0	0	4
35P	0	0	0	0	0	3
35R	0	0	0	0	0	3

13. The percentage of repair performed by each of the following MOS above the UNIT is as follows:

MOS	UTILITY	SCAT
66J	Inspects all repairs performed by 68(4)	
66(1)	Inspects all other repairs	
67(2)	.042	.098
68(3)	.240	.166
68(4)	.224	.332
68G	.135	.104
68H	.045	.031
68K	.090	.072
35(5)	.224	.197

14. The numbers and types of supply MOS are as follows:

MOS	Class III/V Platoon	FSC S&T BN	AMC
55B	25	8	0
76P	0	0	2
76V	0	0	6
77F(76W)*	43	7	0

*76W was rescinded in AR 611-201; April 1986

15. The maximum number of service levels, supply levels and operating levels is four.

16. The maximum number of aircraft operating in one mission profile is five.

17. The maximum number of cycles is twelve.

18. Supply wait times are those times specified in the LHX ALDT model.

19. Personnel and equipment from the Light Infantry Division L series TOE were used to support the mission profiles.

20. The number of mission scenarios that can be operated simultaneously is only limited by the memory of the computer.

Appendix B

List of LHX Documents Reviewed

The following appendix contains a list of the LHX documents reviewed during this research effort.

Application of Hardman to the LHX, In-Progress Review	Apr 1986
Army Science Board Final Report of the ADHOC Subgroup on the Army's LHX Program	Dec 1984
ARTI Program Management Plan	Nov 1984
A Computer Analysis to Predict Crew Workload During LHX Scout-Attack Missions, Vol I, II	Oct 1984
DCSPER Guidance Letter: LHX Milestone I/II Decision Review by ASARC	Nov 1985
Draft LHX FSD RFP	Nov 1986
Human Factors Engineering Analysis (HFEA)	Jun 1986
HTI Draft Final LHX Organizational Modeling Report	Jan 1987
Individual and Collective Training Plan (ICIP)	Dec 1985
Integrated Logistics Support Plan (ILSP)	Nov 1985
Letter of Agreement (LOA)	Mar 1985
LHX Mission Profiles	May 1983
LHX Required Operational Capabilities (ROC)	Nov 1985
LHX System MANPRINT Management Plan	Jun 1986
MANPRINT Primer	Jan 1986
New Equipment Training Plan (NETP)	Sep 1985
Operational and Organizational Plan (O & O Plan)	Apr 1985
PM/Material Systems Assessment	May 1986
RAM Rationale Report	Nov 1985
System Attributes Document	Feb 1984

Target Audience Description	Aug 1985
Tentative Basis of Issue Plan (TBOIP)	Aug 1986
Test and Evaluation Master Plan (TEMP)	Nov 1985
Trade-Off Analysis (TOA)	May 1985
Training Qualitative and Quantitative	Dec 1985
Personnel Requirements Information (TQQPRI)	Jan 1987
Turnkey Analysis	

Early MPT Estimation Methods: An Evaluation of the LHX Test-Bed Research Program

Volume II

EARLY MPT ESTIMATION METHODS: AN EVALUATION OF THE LHX TEST-BED RESEARCH PROGRAM, VOLUME II

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EARLY MPT ESTIMATION METHODS: AN EVALUATION OF THE LHX TEST-BED RESEARCH PROGRAM, VOLUME II

Introduction

This volume contains a description of the three models, MANCAP (Manpower and Mission Capability), EAM (Electronics Aids to Maintenance), and Unit Training, developed as part of the LHX research program. It contains copies of the software, instructions for loading and running the models, and sample outputs of each model. The sections of this volume correspond to the individual models and are further subdivided into "Model Instructions" and "Sample Outputs." The software associated with each model can be obtained by contacting the Commander, U.S. Army Research Institute for the Behavioral and Social Sciences, ATTN: Manned Systems Group, 5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600.

MANCAP

MANCAP is a computer-based model that estimates mission capability of a weapon system based upon weapon system characteristics, operating organization characteristics, and mission performance profiles. The model is comprised of three modules, the Operations and Simulation Module, the Supply Support Module, and the Operator Support Module. These modules can be exercised concurrently or as stand-alone modules. The Supply and Operator Support modules are Lotus 1-2-3 spreadsheet models and are not discussed in this volume due to their simplicity. The Operations and Simulation Module is a Monte Carlo simulation which provides a measure of mission capability expressed in terms of average weapon system starting the mission, average weapon systems completing the mission, average hours operated per weapon system, and the maintenance manpower required to achieve it.

EAM

EAM is a spreadsheet-based model that employs EAM performance data on EAM systems comparable to the EAM system planned for the LHX. The model is a modified Administrative and Logistics Delay Time model which incorporates potential BIT failures in the failure and repair sequence. It allows for the examination of the impact of EAM performance deficiencies on LHX aircraft availability.

Unit training

The Unit training model is a scheduling tool that estimates the training resources required and average unit readiness down time given a particular unit training schedule. By examining and leveling resource consumption over the training period, alternative training schedules can be developed that efficiently employ training resources thereby more effectively training units to mission capable status. The model was used to develop a schedule for unit training of LHX units and for displaced equipment training for those units receiving equipment being displaced by the LHX.

The model developed for this effort is a computer-based model but requires substantial interaction and analysis performed by the operator. The operator must subjectively decide which resources he wants to affect and then rerun the model with a different data set reflecting the changes in resource requirements. Each run of the model must be saved separately.

MANCAP Model

MANCAP Instructions

Hardware Requirements

To run MANCAP, an IBM PC or compatible computer is required. To run many replications of the simulation, it is desirable to use the fastest IBM PC/AT compatible computer available because of the extreme processing needs of the simulation. The computer must be equipped with: 640K of RAM memory, a 360K or 1.2MB floppy disk drive, and a hard disk with at least 1MB of free space. Some type of line printer must be available to print reports produced by the simulation.

Software Requirements

MANCAP requires minimal software to run. MANCAP must be run under MS/PC DOS version 2.0 or greater. A word processor is required to edit and print the reports produced by MANCAP. The word processor must be able to read unformatted text files produced by the simulation (i.e., Micropro Wordstar & Wordstar 2000, Microsoft Word, Word Perfect, etc.). Turbo Pascal Version 4.0 is required if the MANCAP user desires to change any of the simulation parameters.

Installing MANCAP to Hard Disk

First, create a directory in which to store the MANCAP program. Assuming your hard disk is drive C[1], type the following to create a MANCAP directory.

TYPE	ACTION
C:	To log the C drive.
CD C:\	To ensure that the root directory is current.
MKDIR MC	To create a new directory labelled "MC".
CHDIR MC	To make the newly created directory the current directory.

---

[1]This tutorial assumes that the computer hard drive is designated C:, the floppy drive is designated as A:. Appropriate substitutions should be made according to the designation of the floppy and hard drives on the system being used.

Now place the floppy disk labelled MANCAP DISK I into the system's floppy drive and close the drive door. (The following instructions assume the floppy disk is referred to as A:).

TYPE	ACTION
COPY A:*.*	To copy files from MANCAP DISK I to C:\MC

Now place the floppy disk labelled MANCAP DISK II into the system's floppy drive and close the drive door.

TYPE	ACTION
COPY A:*.*	To copy files from MANCAP DISK II.

MANCAP is now installed on the hard disk and ready to be run.

Using MANCAP

Running MANCAP from DOS. MANCAP cannot be run until it is copied to a hard disk. Thus, the previous step of installing MANCAP on the hard disk must be completed before running MANCAP. To start MANCAP, type the following at the DOS prompt:

TYPE	ACTION
MP	To start the MANCAP simulation.

MANCAP will begin by displaying several lines of periods; each period indicates a weapon system being set up in the simulation. To stop the simulation at any time:

TYPE	ACTION
CTRL-SYS REQ	To stop the MANCAP simulation.

While the simulation is running it displays the simulation status on the screen. The status display shows the iteration of the simulation, the current simulation time, the amount of available memory, the largest contiguous block of available memory, and the number of non-contiguous free blocks marked.

Once MANCAP is running, there is a simple menu that can be used to display the status of weapon systems and MOSs for one organization during the run of the simulation. The menu was originally developed to validate the operation of the model. The menu system displays weapon systems in various working, waiting and running states but allows the display of only one command organization and supporting maintenance organization. The views are useful to users to determine immediate impacts of changed parameters. Hitting the enter key three times will bring up the main menu.

The main menu has four selections; the first displays available MOS, the second displays weapon systems that are waiting for MOS and weapon systems being worked on by MOS, and the third shows the location of weapon systems in the command hierarchy. To make a selection from the menu, the number of the selection is typed at the keyboard followed by return. The keypad numbers can be used of the number lock shift is turned on. The last choice from the main menu is to quit the menu and return to the simulation by typing "Q".

If the first menu selection is chosen, a second level menu is activated to select the maintenance level from which the MOS are to be displayed. For each maintenance level, the number of available MOS by type is displayed as well as the associated number of direct, indirect, and other maintenance hours available. Displays are cleared by pressing the return key twice. The view MOS menu is exited by typing "Q" at the menu display.

The second option of the main menu is to view the MOS work and wait queues. When selected, the display of the MOS wait and work queues shows weapon systems that are waiting for a MOS and weapon systems that are being worked on by a MOS. The display of the weapon systems shows the past, present and future events of each weapon system and any MOS that are working on the weapon system. Displays are cleared by pressing the return key. The view MOS Work/Wait menu is exited by typing "Q" at the menu display.

The third option of the main menu is to view command hierarchy weapon systems. Weapon systems in the command hierarchy are either sleeping (have not had a daily this work day or have already gotten a post flight), are ready (have been serviced and are ready to go on mission), or are running (are performing a mission). Weapon systems in each of these categories are displayable from the view command hierarchy menu. The display of the weapon systems shows the past, present and future events of each weapon system and any MOS that are working on the weapon system. Displays are cleared by pressing the return key. The view Command Hierarchy menu is exited by typing "Q" at the menu display.

Compiling and Running MANCAP with Turbo Pascal. Change to the MANCAP directory set up during the MANCAP installation. Insert the Turbo Pascal Program Disk (marked "compiler") into the computer floppy disk drive.

TYPE	ACTION
CD \MC	To change to MANCAP directory
COPY A:*.*	To copy the Turbo Pascal Compiler into the MANCAP directory

TYPE	ACTION
TURBO	To start Turbo Pascal.
ALT-C	To access the compile menu.
P	To choose primary file from the compile menu.
MP.PAS	Enter the name of the main MANCAP program file.
<RET>	Hit the return key.
D	To set the compile destination to disk.
ALT-O	To select the Options menu.
C	To select Compile sub menu.
M	To select program Memory sizes.
S	To pick the Stack size to define.
64000<RET>	To change the default program Stack size.
<ESC><ESC>	To back up to the Options menu.
S	To save the current options just specified.
<RET>	To select the default parameter file name "TURBO.TP".
[Y]	optionally type "Y" to replace any existing parameter file with the one just created.
ALT-C	To access the compile menu.
B	To build (compile) the MANCAP program.
ALT-X	To exit Turbo Pascal.
[Y]	Note: it may not be necessary to type a "Y" if either no file was edited or no changes were made to the file in the editor. Type "Y" to save any changes to the MANCAP file if it was edited.

Now you should be at the dos prompt (C:). Type "MP" to begin running the simulation. At this point the program will run the same as it does from DOS. (See "Running MANCAP from DOS" for instructions regarding accessing menu options).

Changing Parameters of MANCAP Simulation

This section discusses the basic procedures for changing simulation parameters and running the simulation with those changes. Parameters determining the simulation scenario are stored in two pascal program files, "SMLSET.PAS" and "SETUPSVC.PAS". "SMLSET.PAS" contains the parameters to set up the weapon systems, mission profiles, MOS characteristics, supply organization and command organization and "SETUPSVC.PAS" contains the parameters to set up the service organizations. Parameters are modified by loading these program source files into the Turbo Pascal Editor, changing desired parameters and re-compiling the program source files so that the simulation program incorporates the new parameters.

The actions necessary to load the program files and change parameters are as follows:

To Start Turbo Pascal From DOS:

TYPE	ACTION
CD C:\MC	Set current directory to MANCAP directory
TURBO	Start Turbo
F5	To turn on zoom display mode.

To load a file after Turbo Pascal has been started.

TYPE	ACTION
ALT-F	To load the File menu.
L	To load a file.
SETUPSVC or SMLSET	To load a setup file into the Turbo Pascal editor.

To change a parameter, a search is first be done to locate the section of the program where the parameter is set. To search with Turbo Pascal (assuming the previous step has been performed and one of the setup files is loaded into the editor), type the following commands:

TYPE	ACTION
CTRL-Q-R	To move to the beginning of the current file.
CTRL-Q-F	To search for text.
search text[2]	Enter text to search.
<RET><RET>	To begin searching.

The parameter change descriptions given below will locate the editor near parameters to be changed for the simulation. Once the parameter to be changed has been located, modifications are accomplished by: 1) pressing the Ins key on the lower right hand side of the keyboard to turn off the insert, and 2) entering the new parameter value by typing directly over the old parameter value. To save the revised parameter file:

TYPE	ACTION
F2	Function key to save an updated file.

When all necessary parameters have been changed according to the above procedure, recompile the program as was described in "Installing MANCAP to Hard Disk."

MOS Characteristics. Use ALT-F-L as outlined in the Introduction to load the file "SMLSET.PAS" if it is not yet loaded. Move to the top of the file using the CTRL-Q-R key combination. Search for the text "SETUP_MOS" as described in the Introduction. Use the "PgDn" key arrow keys to adjust the editor so that following portion of the "SMLSET" file is on the screen.

```
{****************************  SETUP_MOS  *********************}
{Purpose:  Set up MOS names and direct/indirect time percentages
for each MOS type.}

Input:

Output:
```

---

[2]Actual search text is presented in the next section by type parameter.

```
{****************************     SETUP_MOS     ********************}
begin
  with MOS[1] do begin
    lbl          := '67V';    {******* Crew Chief for OH-58 *******}
    percent_indirect := 21;
    percent_direct   := 28;
    end; { with }
  with mos[2] do begin
    lbl          := '67Y';    {******* Crew Chief for AH-1 *******}
    percent_indirect := 21;
    percent_direct   := 28;
    end; { with }
  with mos[3] do begin
    lbl          := '67N';    {******* Crew Chief for UH-1H *******}
    percent_indirect := 21;
```

Each MOS type is an element of an MOS array. Each element of the MOS array contains a description of the characteristics of a single MOS which include, the type of MOS and the percentage of direct and indirect time. The element of the MOS array is referenced by the "with do begin" statement preceding the description of each MOS element, (i.e., with mos[1] do begin).

To change an MOS name and percentages make sure the "INS" key is off (determine whether "Insert" indicator is off by checking the status indicator at the top of the Turbo Pascal screen) and type over the existing name and percentage. The new MOS will replace the existing MOS everywhere the MOS array element number is referenced in the simulation such as in setting up the maintenance organizations. To add MOS types to the simulation, the maximum number of MOS types "n_MOS" must be changed in the file "DATAS.PAS" to reflect the new maximum number of MOS. To change the value of "n_mos", load the file "DATAS.PAS" and search for the text "n_mos" (after moving to the beginning of the file).This is accomplished by using the procedures outlined in the Introduction. If all parameter changes to the current file are completed, save the work file by hitting the F2 function key. If no more parameter changes are to be made, recompile MANCAP, and run the simulation as outlined in "Compiling and Running MANCAP with Turbo Pascal."

<u>Weapon System Ram Characteristics</u>. Use ALT-F-L as outlined in the Introduction to load the file "SMLSET.PAS" if it is not yet loaded. Move to the top of the file using the CTRL-Q-R key combination. Search for the text "SETUP_WS" as described in the Introduction. Using the "PgDn" key and arrow keys adjust the editor position in the source program file so that following portion of the "smlset" file should is on the screen.

```
with ws[1] do begin  (************  THE OH-58 DATA  ************)
  lbl          := 'OH-58';
  MTBF         := 760;
  MTEMA        := 370;
  MTTR         := 45;
  needs_parts:= 27;
  lvl_svc_perc[1] := 80;   (****** Flight Line Repairable ******)
  lvl_svc_perc[2] := 90;   (****** Level two   Repairable ******)
  lvl_svc_perc[3] := 100;  (****** Level three Repairable ******)
  lvl_svc_perc[4] := 100;  (****** Level four  Repairable ******)
  lvl_spply_perc[1] := 36;  (*** Level One   Parts Available ***)
  lvl_spply_perc[2] := 64;  (*** Level Two   Parts Available ***)
  lvl_spply_perc[3] := 85;  (*** Level Three Parts Available ***)
  lvl_spply_perc[4] := 100; (*** Level Four  Parts Available ***)

  with mos_pref[1] do begin (******  Crew Chief for OH-58 ******)
    percent_chosen   := 950;
    percent_ti       := 0;
    ti_mos_n         := 0;
    time_ti          := 0;
    end; { with mos_pref[n] }

  with mos_pref[2] do begin (******  Crew Chief for AH-1   ******)
```

The variable characteristics for each weapon system include the mean time between mission affecting failure (MTBF), the mean time between essential maintenance action (MTEMA), the mean time to repair (MTTR), the percentage of repairs needing parts (needs_parts), the likelihood of being repaired at each of the service levels (lvl_svc_perc), and the likelihood of having parts at each supply level (lvl_spply_perc).

When a weapon system is repaired above the flight line, a MOS that will provide service for the weapon system must be determined. Below the settings for weapon system RAM characteristics are settings for how MOS are chosen and when a particular MOS is chosen, whether or not the repair performed is given a technical inspection, who performs the technical inspection, and how long the technical inspection takes. For each weapon system, each MOS has the following characteristics: 1) percentage of work performed (percent_chosen), 2) percentage of repairs given a technical inspection (percent_ti), 3) MOS performing the technical inspection (ti_mos_n), and 4) length of technical inspection (time_ti).

Immediately succeeding the code to specify weapon system MOS preferences for non flight line repairs, are weapon system MOS preferences for flight line repairs (such as mission recoveries and post flights). For each flight line repair task, the mos to be used is specified (mos_n), the time that the mos is needed to perform the desired task (time_mos), the percent of time the service gets a technical inspection (percent_ti), the time required to perform a ti (time_ti), and the priority of the repair (priority).

```
{************* SET UP OH-58 LVL 1 MOS PREFERENCES **************}

  with downed do begin       {************  DOWNED  *************}
    mos_n              := 1;
    time_mos           := 100;
    percent_ti         := 0;
    ti_mos             := 0;
    time_ti            := 0;
    priority           := 1;
    end; { with downed }
  with daily do begin        {************   DAILY   ************}
    mos_n              := 1;
    time_mos           := 100;
    percent_ti         := 0;
    ti_mos             := 0;
    time_ti            := 0;
    priority           := 2;
    end; { with daily }
  with launch do begin       {************  LAUNCH  *************}
    mos_n              := 1;
    time_mos           := 25;
    percent_ti         := 0;
    ti_mos             := 0;
    time_ti            := 0;
    priority           := 3;
    end; { with launch }
```

The parameters for each weapon system are modifiable within the constraints of the model, by simply typing over the old parameter, and recompiling the modified program file as described in "Compiling and Running MANCAP with Turbo Pascal." If all parameter changes to the current file are completed, save the work file by hitting the F2 function key. If no more parameter changes are to be made, recompile mancap, and run the simulation as outlined in the Introduction.

Mission Profiles. To modify parameters pertaining to the mission scenarios simulated, use ALT-F-L to load the file "SMLSET.PAS" if it is not yet loaded. Move to the top of the file using the CTRL-Q-R key combination. Search for the text "SETUP_MSNS" as described in the Introduction. Use the "PgDn" key and cursor keys to adjust the editor in order to view the parameters that are set for each mission type. The following portion of the smlset file should appear on the screen.

```
begin
  with msns[1] do begin        {********** Recon Msns **********}
    lbl          := 'Recon 1';
    duration     := 300;
    ws_rqd[1]    := 4; { oh-58 }
    ws_fnsh[1]   := 0; { oh-58 }
    ws_rqd[2]    := 2; { ah-1 }
    ws_fnsh[2]   := 0; { ah-1 }
    mtbf_per     := 100;
```

```
    mtema_per       := 100;
    end; { with msns[1] }

  with msns[2] do begin
    lbl             := 'Recon 2';
    duration        := 300;
    ws_rqd[1]       := 2; { oh-58 }
    ws_fnsh[1]      := 0; { oh-58 }
    ws_rqd[2]       := 1; { ah-1 }
    ws_fnsh[2]      := 0; { ah-1 }
```

Each mission type is identified by a unique number located within the brackets [] in the "with msns[]". Each mission type has a name (lbl), and a mission length (duration). Each mission type also has a required number of weapon systems to start the mission, (ws_rqd[]), and a required number of weapon systems to complete a mission successfully (ws_fnsh[]). Weapon system failure rates can also be determined on a mission by mission basis by the variables (mtbf_per) and (mtema_per). (Mtbf_per) and (mtema_per) are the percent of impact a mission type has on a weapon systems failure time. For instance if (mtbf_per) is set to 200, then the weapon system will fail twice as quickly performing this mission profile.

The parameters for each mission type are modifiable within the constraints of the model, by simply typing over the old parameter as described in the Introduction, saving the modified file, and recompiling the modified program file as described in "Compiling and Running MANCAP with Turbo Pascal."

Supply Hierarchy Characteristics. Use ALT-F-L as outlined in the introduction to load the file "SMLSET.PAS" if it is not yet loaded. Move to the top of the file using the CTRL-Q-R key combination. Search for the text "SETUP_SPPLY" as described in the Introduction. Use the "PgDn" key to see the parameters that are set for each supply level. The following portion of the SMLSET file should be on the screen.

```
for i := 1 to n_spply_lvl4 do begin
  with spply_h[i].spply4_aldt do begin
    lbl                 := 'conus';
    parts_round_trip := 21600;
    end; { with }
  for j := 1 to n_spply_lvl3 do begin
    with spply_h[i].spply3[j].spply3_aldt do begin
      lbl                 := 'theater';
      parts_round_trip := 2400;
      end; { with }
    for k := 1 to n_spply_lvl2 do begin
      with spply_h[i].spply3[j].spply2[k].spply2_aldt do begin
        lbl                 := 'ASL';
        parts_round_trip := 100;
        end; { with }
      for l := 1 to n_spply_lvl1 do begin
```

```
        with spply_h[i].spply3[j].spply2[k].spply1[l] do begin
          lbl               := 'PLL      ';
          lbl[6]            := chr(l+ORD('0'));
          parts_round_trip := 0;
          end; { with }
        end; { for l }
      end; { for k }
    end; { for j }
  end; { for i }
```

In the supply hierarchy, only the names of the supply levels (lbl), and the round trip times (parts_round_trip) to each supply location are variable.

The supply parameters are modifiable within the constraints of the model, by simply typing over the old parameter (as described in the Introduction, and recompiling the modified program file as described in "Compiling and Running MANCAP with Turbo Pascal").

Service Hierarchy Characteristics. To modify the service hierarchy, load the file "SETUPSVC.PAS" using the procedure described in the Introduction. Search for the text "SETUP_AMC" as described in the Introduction. After searching for "SETUP_AMC" the editor will display the level 3 service hierarchy which is the AMC in this application. Use the "PgDn" and arrow keys to view the portion of the program file shown below.

```
lbl := 'AMC LVL3';
  create_init_ws_obj(floats, 1, 1, 1, 0, 0, wss[1], tail_n,
                     is_float);
  create_init_ws_obj(floats, 1, 1, 1, 0, 0, wss[1], tail_n,
                     is_float);
  create_init_ws_obj(floats, 2, 1, 1, 0, 0, wss[2], tail_n,
                     is_float);
  create_init_ws_obj(floats, 2, 1, 1, 0, 0, wss[2], tail_n,
                     is_float);
  set_coord(float_coord, 1, 1, 0, 0); set_coord(no_coord, 0, 0,
          0, 0);
  set_event_data(curr_event, float, float_coord, no_time,
                 not_set, no_coord, unknwn, no_pri, no_cc, no_mos,
                 no_time_as, mcnotrdy);
  new_float := nil;
  while (floats <> nil) do begin
    leave_cmd(floats, curr_ws);
    leave_event(curr_ws.curr_event, asleep_event);
    enter_event(curr_ws.curr_event, curr_event);
    enter_cmd(new_float , curr_ws);
    end; { while }
  replace_cmd(floats, new_float);
```

```
{**************************   SHIFT1   ***************************}

  with shift1 do begin
    start_t := 0;
    stop_t  := 1200;

    mos_total[1]  :=     5;      { 67V   }
    mos_total[2]  :=     6;      { 67Y   }
    mos_total[3]  :=     9;      { 67N   }
    mos_total[4]  :=     1;      { 66V   }
    mos_total[5]  :=     1;      { 66Y   }
    mos_total[6]  :=     2;      { 66N   }
    mos_total[7]  :=     1;      { 66J   }
```

The first line of code sets the name of the current service location (lbl). The shift start time (start_t) and end (end_t) time are entered for the first shift. The number each mos type on the first shift at this level are defined by loading values into the array "mos_total[]". Each entry in "mos_total" corresponds to an MOS defined in "SETUP_MOS" (See "MOS Characteristics") . After the MOS are set up to work on shift one at the specified service level, MOS are set up to work on shift two.

Additional service level parameters are supplied in the code that follows. Use the "PgDn" and arrow keys to display the following code.

```
  working := nil;
  waiting := nil;
  set_coord(spply_choice, 1, 1, 1, 4);
  time_to_spply    := 50;
  time_to_next_lvl := 0;
  end; { with svc_mos }
```

This segment of code allows the user to change the time to the supply organization from the current service organization (time_to_spply), and the time to the next higher service organization from the current service organization (time_to_next_lvl). As with each of the previous segments of code, these variables can be modified by typing over their current values (Introduction) and re-compiling the program (Compiling and Running MANCAP with Turbo Pascal). The setup for each of the other service locations is similar to the setup for the AMC. To view and modify each of the other service locations, the names of the service locations to search for are:

SETUP_RECON_LVL2
SETUP_RECON_LVL1
SETUP_AHC_LVL2
SETUP_AHC_LVL1
SETUP_UTIL_LVL2
SETUP_UTIL_LVL1.

Command Hierarchy Characteristics. Use ALT-F-L as outlined in the introduction to load the file "SMLSET.PAS" if it is not yet loaded. Move to the top of the file using the CTRL-Q-R key combination. Search for the text "SETUP_AHC" as described in the Introduction. The search will display the command hierarchy for the attack organizations. Use the "PgDn" and "arrow" keys to view the portion of the program file shown below.

```
with cmd_lvl2 do begin { clear all }
  lbl := 'AHC';
  for l := 1 to n_cmd_lvl1 do
    clear_cmd(cmdl[l]);

  ws_type1 := 4; ws_type2 := 7; ws_type3 := 0;

  for l := 1 to 3 do begin
    populate_ws(cmdl[l], i, j, k, l, wss, ws_type1, ws_type2,
               ws_type3, tail_n);
    with cmdl[l] do begin
      lbl       := 'AHC FL';
      lbl[9]    := chr(l+ORD('0'));
      set_coord(svc_choice, i, j, k, l);
      end; { with  cmdl }
    end; { for l }
```

This portion of code sets up the name of the command organization (lbl) and populates each organization with weapon systems. The underlined line in the above code determines the number of each type of weapon system in the organization and can be changed by simply entering a different number of each weapon system (the weapon system number is defined in SETUP_WS).

The next segment of code displayed below determines the missions each command organization is to perform.

```
with cmdl[1] do begin
  cycle_length := 1800;
  add_msn(std_msn, 3, 100, msns[3]);
  add_msn(std_msn, 3, 400, msns[3]);
  end; { with }

with cmdl[2] do begin
  cycle_length := 1800;
  std_msn := nil;
  add_msn(std_msn, 3, 700, msns[3]);
  add_msn(std_msn, 3, 1000, msns[3]);
  end; { with }

with cmdl[3] do begin
  cycle_length := 1800;
  add_msn(std_msn, 3, 1300, msns[3]);
  add_msn(std_msn, 3, 1600, msns[3]);
  end; { with }
end; { with cmd_lvl2 }
```

The above sequence of code designates that organization one (cmdl[1]) is to perform missions on a cycle length (cycle_length) of 18.00 hours. The function add_msn adds missions to a list of standard missions (std_msn) the command organization is to perform. The standard mission list (std_msn) is used to assign missions to be performed at the start of each mission cycle. The function add_msn is used twice to add missions to the first command organization. Both uses of add_msn add a mission of type 3 (mission type numbers are determined in SETUP_MSNS) to the list of standard missions the command organization is to perform. The first use of add_msn adds a mission at time 100, which is one hour from the start of the mission cycle. The second use of add_msn adds a mission at time 400, four hours from the start of the mission cycle. The second organization (cmdl[2]) is to perform missions on an 18.00 hour cycle (cycle_length) and is to perform a mission of type 3, 7.00 hours after the start of the mission cycle (add_msn(std_msn, 3, 700, msns[3]).

The cycle length (cycle_length), mission type, and mission start times (add_msn(std_msn, 3, 700, msns[3]) for each command organization can be set by overwriting the current values of the parameters. The parameters for the recon organizations is found by searching for "SETUP_RECON", parameters for the utility organization are found by searching for "SETUP_UTIL".

Output Data

To a File. Program output is automatically sent to an output file named "OUT.DAT". This file is cleared and rewritten each time the program is run, so remember to rename (using the DOS "Rename" command) the current output file to save it before running the program again. When running the simulation for eight replications the output file takes about 400 - 500K of disk space, so have this much disk space available to run the program.

To the Printer. To print simulation output, the files should be read into a word processor, formatted as necessary and printed. Mancap prints a report of cumulative statistics for the simulation at the end of each replication. It is likely that only the last of these reports is needed and the previous reports can be deleted in the word processor. To accommodate the size of some of the tables, the widest margins and smallest print fonts available should be used and manual page breaks should be inserted.

MANCAP Outputs for the LHX and Predecessor Systems

The following pages contain the outputs of the LHX and predecessor application of the PC version of MANCAP. The data for the LHX and predecessor aircraft were obtained from eight replication runs of three days each. The data are presented in 33 tables for the LHX run and 45 tables for the predecessor application. Presented below is a description and example of each type of table.

Table 1 is presented separately for each mission scenario. Additionally, the reconnaissance mission is presented in two tables, one displaying the mission frequency count for the two aircraft mission and the other for the five aircraft mission. The columns represent the number of aircraft available to begin a mission and the rows represent the number of aircraft completing a mission. The cells are the number of aircraft completing a mission given the number that are launched. The cell values are cumulative over the length of the simulation (eight replications). The percentages in the most right column are the percentage of aircraft that complete a mission. For example, 8.8% of the missions launched complete the mission with three or less aircraft. The percentages at the bottom of the table are the percentage of aircraft that are available for a mission launch. For example, 90.6% of the time, there are eight aircraft available to begin a mission.

Table 1

Mission Frequency Count

MISSION FREQUENCY COUNT

FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS)

Weapon System LKXS Mission Name = ARC RSN 1

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	16	.	.	.	16	8.3%
7	.	.	.	.	.	.	.	.	36	.	.	.	36	18.8%
6	.	.	.	.	.	.	.	3	51	.	.	.	54	28.1%
5	.	.	.	.	.	.	1	2	40	.	.	.	43	22.4%
4	.	.	.	.	.	.	3	3	20	.	.	.	26	13.5%
3	.	.	.	.	1	.	1	3	8	.	.	.	13	6.8%
2	.	.	.	.	1	.	.	.	1	.	.	.	2	1.0%
1	.	.	.	.	.	.	.	.	2	.	.	.	2	1.0%
0	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
Column Total	0	0	0	0	2	0	5	11	174	0	0	0		
Percent	0.0	0.0	0.0	0.0	1.0	0.0	2.6	5.7	90.6	0.0	0.0	0.0		

Table 2 is also presented separately for the three mission scenarios. The data for the reconnaissance mission is presented in two tables, one displaying the average mission times for the two aircraft mission and the other for the five aircraft mission. The columns represent the number of aircraft available to begin a mission. The rows represent the number of aircraft who complete a mission given the number that are launched. The cells of the table are the average flying times for each combination of launches and mission completions. In this example, the average flying time for the situation where seven aircraft begin a mission and only four aircraft complete is 2.24

hours. The cells on the diagonal are equal to the mission duration specified in the set up routine since the number of aircraft that begin a mission and the number of aircraft that complete a mission are equal.

Table 2

Average Flying Time Per Aircraft Launched

AVERAGE FLYING TIME PER ACFT LAUNCHED

FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS)

Weapon System LHXS === Mission Name = AHC MSN 1

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	3.00	.	.	.
7	.	.	.	.	.	.	.	.	2.78	.	.	.
6	.	.	.	.	.	.	.	2.83	2.61	.	.	.
5	.	.	.	.	.	.	2.74	2.39	2.39	.	.	.
4	.	.	.	.	.	.	2.32	2.26	2.18	.	.	.
3	.	.	.	.	2.53	.	2.34	2.26	1.99	.	.	.
2	.	.	.	.	2.22	.	.	.	1.38	.	.	.
1	.	.	.	.	.	.	.	.	1.51	.	.	.
0	.	.	.	.	.	.	.	.	.	.	.	.

Average mission time = 2.52

Table 3 displays the average time per aircraft spent in a "Not Mission Capable Maintenance," or "Not Mission Capable Supply" status at each level. It is the total down time of the aircraft and thus includes supply times, awaiting personnel times, and transit times. The transit times are presented separately from the repair levels. This table is displayed for each of the mission scenarios by aircraft type. For the LHX application, there is one table per mission profile. For the predecessor application, there are two tables for the Attack and Reconnaissance profile, one for the OH-58 and one for the AH-1.

Table 3

Average Aircraft Time to Repair at Each Service Level

Aircraft Hours Per Day at Each Service Level

Attack LHXS

Category	Process Time
On Flight Line	3.7350
Flight Line to MSC	0.0486
At MSC	5.0131
Flight Line to AMC	0.1111
At AMC	6.0867
AMC to Flight Line	0.0549
MSC to Flight Line	0.0480

Table 4 is displayed for each mission profile and each type aircraft. The columns represent the service level at which the aircraft is repaired and the rows represent the level from which the aircraft is supplied. The cells display the number of repairs at a given level of service and a given level of supply. The cells are the total numbers of repairs at each level over eight replications. The percentages displayed at the bottom of the table represent the percentage of total repairs performed at each service level.

Table 4

Frequency of Repair

FREQUENCY OF REPAIR (Eight Replications)

Attack LHXS

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	377	44	49	0
PLL Shop Stock	142	23	21	0
ASL	47	5	13	0
Theater	37	5	6	0
Conus	2	0	0	0
TOTAL	605	77	89	0
Percent of Total	78.5%	10.0%	11.5%	0.0%

Total Repairs = 771

Table 5 is similar to Table 4 and is displayed for each mission profile and each type aircraft. The columns represent the service level at which the aircraft is repaired and the rows represent the level from which the aircraft is supplied. The cells display the average repair time per aircraft at a given level of repair and a given level of supply. The average repair times for aircraft receiving parts from CONUS or theater may include events that were not yet complete at the end of the

simulation run and therefore cause average repair times at those locations to appear low. In those cases, the table contains a note at the bottom of the table indicating the number of repair events that were not complete at the end of the simulation.

Table 5

Average Aircraft Repair Times

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)			
	Attack	LRUS	
Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	1.19	2.89	6.68
PLL Shop Stock	2.19	3.75	3.92
ASL	3.16	6.30	5.95
Theater	7.62	28.21	25.45
Conus	208.05	0.00	0.00

Table 6 displays the cumulative statistics for MOS are presented for each servic. organization. The service organizations included are:

AHC Flight Line
HSC
Recon Flight Line
HHT
Utility Flight Line
Utility Level 2
AMC

The AMC contains statistics for all three mission profiles. Although there is not a Utility Level 2 service organization, the table was included to display the workload statistics for Utility repairers located on the flight line who perform repairs and require a technical inspection, unlike the repairs performed by the crew chief who do not require a technical inspection.

Table 6 displays the MOS, the number of each type MOS allocated by shift, the direct maintenance manhours, indirect maintenance manhours, and other maintenance manhours by MOS for the total simulation run (8 replications). The required workload was calculated from the maintenance manhours per day of direct and indirect maintenance performed by each MOS assuming a maximum requirement of 3.4 hours/day direct maintenance and 2.5 hours/day indirect maintenance. The strength required was then determined as the number of people required to perform the work generated by the simulation.

Table 6

MOS Cumulative Statistics

Level 1

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

AHC LVL1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	11	0	715.50	220.75	251.65	1187.90	11.67	12.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

AHC LVL1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	11	0	679.00	191.50	325.71	1196.21	10.67	11.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

AHC LVL1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	11	0	657.75	178.50	398.61	1234.86	10.25	11.00

Level 2

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

AHC LVL2

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	8	7	6.25	0.50	0.00	6.75	0.08	1.00
66J	1	0	23.04	0.00	0.00	23.04	0.28	1.00
661	4	3	50.88	0.00	0.00	50.88	0.62	1.00
683	2	2	23.75	4.50	0.00	28.25	0.35	1.00
684	5	4	30.00	5.00	0.00	35.00	0.43	1.00
68C	2	1	10.00	2.50	0.00	12.50	0.15	1.00
68K	1	0	6.25	1.50	0.00	7.75	0.09	1.00
355	5	4	20.00	2.50	0.00	22.50	0.28	1.00

Level 3

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

AHC LVL3

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	19	18	23.00	4.00	0.00	27.00	0.33	1.00
66J	1	0	62.48	0.00	0.00	62.48	0.77	1.00
661	4	4	109.44	0.00	0.00	109.44	1.34	2.00
683	6	5	43.75	6.50	0.00	50.25	0.62	1.00
684	6	6	78.75	13.50	0.00	92.25	1.13	2.00
68C	2	2	28.75	6.50	0.00	35.25	0.43	1.00
68H	2	1	10.00	1.00	0.00	11.00	0.13	1.00
68K	1	0	13.75	2.00	0.00	15.75	0.19	1.00
355	8	7	28.75	5.50	0.00	34.25	0.42	1.00

LHX Outputs

Table 7

Mission Frequency Count - Attack

MISSION FREQUENCY COUNT

FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS)

Weapon System LHXS Mission Name = AHC MSN 1

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	16	.	.	.	16	8.3%
7	.	.	.	.	.	.	.	.	36	.	.	.	36	18.8%
6	.	.	.	.	.	.	.	3	51	.	.	.	54	28.1%
5	.	.	.	.	.	.	1	2	40	.	.	.	43	22.4%
4	.	.	.	.	.	.	3	3	20	.	.	.	26	13.5%
3	.	.	.	.	1	.	1	3	8	.	.	.	13	6.8%
2	.	.	.	.	1	.	.	.	1	.	.	.	2	1.0%
1	.	.	.	.	.	.	.	.	2	.	.	.	2	1.0%
0	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
Column Total	0	0	0	0	2	0	5	11	174	0	0	0		
Percent	0.0	0.0	0.0	0.0	1.0	0.0	2.6	5.7	90.6	0.0	0.0	0.0		

Table 8

Mission Frequency Count - Recon

MISSION FREQUENCY COUNT

FOR EIGHT REPLICATIONS (TOTAL = 144 MISSIONS)

Weapon System LHXS === Mission Name = Recon 1

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
7	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
6	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
5	.	.	.	.	.	30	.	.	.	.	.	.	30	20.8%
4	.	.	.	.	4	46	.	.	.	.	.	.	50	34.7%
3	.	.	.	.	5	37	.	.	.	.	.	.	42	29.2%
2	.	.	.	1	2	14	.	.	.	.	.	.	17	11.8%
1	.	.	.	.	.	4	.	.	.	.	.	.	4	2.8%
0	.	.	.	1	.	.	.	.	.	.	.	.	1	0.7%
Column Total	0	0	0	2	11	131	0	0	0	0	0	0		
Percent	0.0	0.0	0.0	1.4	7.6	91.0	0.0	0.0	0.0	0.0	0.0	0.0		

MISSION FREQUENCY COUNT

FOR EIGHT REPLICATIONS (TOTAL = 96 MISSIONS)

Weapon System LHXS === Mission Name = Recon 2

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
7	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
6	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
5	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
4	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
3	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
2	.	.	44	.	.	.	.	.	.	.	.	.	44	45.8%
1	.	.	40	.	.	.	.	.	.	.	.	.	40	41.7%
0	.	1	11	.	.	.	.	.	.	.	.	.	12	12.5%
Column Total	0	1	95	0	0	0	0	0	0	0	0	0		
Percent	0.0	1.0	99.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

Table 9

Mission Frequency Count - Utility

MISSION FREQUENCY COUNT

FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS)

Weapon System LHX-U === Mission Name = Utility

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
7	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
6	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
5	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
4	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
3	.	.	.	94	.	.	.	.	.	.	.	.	94	49.0%
2	.	.	6	61	.	.	.	.	.	.	.	.	67	34.9%
1	.	.	5	21	.	.	.	.	.	.	.	.	26	13.5%
0	1	.	.	4	.	.	.	.	.	.	.	.	5	2.6%
Column Total	1	0	11	180	0	0	0	0	0	0	0	0		
Percent	0.5	0.0	5.7	93.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

LHX Outputs

Table 10

Average Flying Time Per Acft Launched - Attack

================== AVERAGE FLYING TIME PER ACFT LAUNCHED ========================

========================== FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS) =======

=== Weapon System LHXS === Mission Name = ANC MSN 1 ================================

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING											
	0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	3.00	.	.	.
7	.	.	.	.	.	.	.	.	2.78	.	.	.
6	.	.	.	.	.	.	.	2.83	2.61	.	.	.
5	.	.	.	.	.	.	2.74	2.39	2.39	.	.	.
4	.	.	.	.	.	.	2.32	2.24	2.18	.	.	.
3	.	.	.	.	2.53	.	2.34	2.24	1.99	.	.	.
2	.	.	.	.	2.22	.	.	.	1.38	.	.	.
1	.	.	.	.	.	.	.	.	1.51	.	.	.
0	.	.	.	.	.	.	.	.	.	.	.	.

Average mission time = 2.52

LHX Outputs

Table 11

Average Flying Time Per Acft Launched - Recon

================== AVERAGE FLYING TIME PER ACFT LAUNCHED ========================
========================== FOR EIGHT REPLICATIONS (TOTAL = 144 MISSIONS) =======
=== Weapon System LHXS === Mission Name = Recon 1 ================================
=== AIRCRAFT ===|========== NUMBER OF AIRCRAFT STARTING ==========================

COMPLETING	0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	3.00	.	.	.	.	.	.
4	.	.	.	.	3.00	2.68	.	.	.	.	.	.
3	.	.	.	.	2.57	2.37	.	.	.	.	.	.
2	.	.	.	2.68	1.84	2.00	.	.	.	.	.	.
1	.	.	.	.	.	1.91	.	.	.	.	.	.
0	.	.	.	1.48	.	.	.	.	.	.	.	.

Average mission time = 2.56

================== AVERAGE FLYING TIME PER ACFT LAUNCHED ========================
========================== FOR EIGHT REPLICATIONS (TOTAL = 96 MISSIONS) =======
=== Weapon System LHXS === Mission Name = Recon 2 ================================
=== AIRCRAFT ===|========== NUMBER OF AIRCRAFT STARTING ==========================

COMPLETING	0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.	.	.	.	.	.
3	.	.	.	.	.	.	.	.	.	.	.	.
2	.	.	3.00	.	.	.	.	.	.	.	.	.
1	.	.	2.18	.	.	.	.	.	.	.	.	.
0	.	2.78	1.28	.	.	.	.	.	.	.	.	.

Average mission time = 2.46

Table 12

Average Flying Time Per Acft Launched - Utility

AVERAGE FLYING TIME PER ACFT LAUNCHED

FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS)

Weapon System LHX-U === Mission Name = Utility

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.	.	.	.	.	.
3	.	.	.	3.00	.	.	.	.	.	.	.	.
2	.	.	3.00	2.47	.	.	.	.	.	.	.	.
1	.	.	2.17	1.91	.	.	.	.	.	.	.	.
0	0.00	.	.	1.24	.	.	.	.	.	.	.	.

Average mission time = 2.64

LHX Outputs

Table 13

Aircraft Hours Per Day at Each Service Level - Attack

Aircraft Hours Per Day at Each Service Level

Attack — LHXS

Category	Process Time
On Flight Line	3.7350
Flight Line to HSC	0.0486
At HSC	5.0131
Flight Line to AMC	0.1111
At AMC	6.0867
AMC to Flight Line	0.0549
HSC to Flight Line	0.0480

LHX Outputs

Table 14

Aircraft Hours Per Day at Each Service Level - Recon

Aircraft Hours Per Day at Each Service Level

Recon — LHXS

Category	Process Time
On Flight Line	2.6754
Flight Line to NSC	0.0635
At NSC	6.3526
Flight Line to AMC	0.1021
At AMC	6.3410
AMC to Flight Line	0.0500
NSC to Flight Line	0.0625

LHX Outputs

Table 15

Aircraft Hours Per Day at Each Service Level - Utility

Aircraft Hours Per Day at Each Service Level

Utility — LHX-U

Category	Process Time
On Flight Line	3.0066
Flight Line to MSC	0.0000
At MSC	9.2400
Flight Line to AMC	0.1146
At AMC	6.1817
AMC to Flight Line	0.0000
MSC to Flight Line	0.0000

Table 16

Aircraft Hours Per Day at Each Service Level - Floats

Aircraft Hours Per Day at Each Service Level

Floats — LHXS

Category	Process Time
On Flight Line	0.0000
Flight Line to HSC	0.0000
At HSC	0.0000
Flight Line to AMC	0.0000
At AMC	21.7600
AMC to Flight Line	0.0104
HSC to Flight Line	0.0000

Aircraft Hours Per Day at Each Service Level

Floats — LHX-U

Category	Process Time
On Flight Line	0.0000
Flight Line to HSC	0.0000
At HSC	0.0000
Flight Line to AMC	0.0000
At AMC	25.9600
AMC to Flight Line	0.0000
HSC to Flight Line	0.0000

LHX Outputs

Table 17

Frequency of Repair - Attack

FREQUENCY OF REPAIR (Eight Replications)

Attack LHXS

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	377	44	49	0
Pll Shop Stock	142	23	21	0
Asl	47	5	13	0
Theater	37	5	6	0
Conus	2	0	0	0
TOTAL	605	77	89	0
Percent of Total	78.5%	10.0%	11.5%	0.0%

Total Repairs = 771

Table 18

Frequency of Repair - Recon

FREQUENCY OF REPAIR (Eight Replications)

Recon <====> LHXS

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	299	37	29	0
Pll Shop Stock	115	19	12	0
Asl	36	4	4	0
Theater	19	1	5	0
Conus	1	0	0	0
TOTAL	470	61	50	0
Percent of Total	80.9%	10.5%	8.6%	0.0%

Total Repairs = 581

LHX Outputs

Table 19

Frequency of Repair - Utility

FREQUENCY OF REPAIR (Eight Replications)

Utility LHX-U

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	69	0	24	0
PLL Shop Stock	30	1	10	0
ASL	8	0	5	0
Theater	6	0	2	0
Conus	0	0	0	0
TOTAL	113	1	41	0
Percent of Total	72.9%	0.6%	26.5%	0.0%

Total Repairs = 155

Table 20

Frequency of Repair - Floats

FREQUENCY OF REPAIR (Eight Replications)

Floats <====> LHXS

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	0	0	0	0
Pll Shop Stock	0	0	0	0
Asl	0	0	0	0
Theater	0	0	9	0
Conus	0	0	1	0
TOTAL	0	0	10	0
Percent of Total	0.0%	0.0%	100.0%	0.0%

Total Repairs = 10

FREQUENCY OF REPAIR (Eight Replications)

Floats <====> LHX-U

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	0	0	0	0
Pll Shop Stock	0	0	0	0
Asl	0	0	0	0
Theater	0	0	1	0
Conus	0	0	0	0
TOTAL	0	0	1	0
Percent of Total	0.0%	0.0%	100.0%	0.0%

Total Repairs = 1

LHX Outputs

Table 21

Average Time to Repair at Each Service Level - Attack

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)

Attack LHXS

Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	1.19	2.89	4.68
Pll Shop Stock	2.19	3.75	3.92
Asl	3.14	6.30	5.95
Theater	7.62	28.21	25.45
Conus	208.05	0.00	0.00

LHX Outputs

Table 22

Average Time to Repair at Each Service Level - Recon

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)

Recon <====> LHXS

Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	1.14	3.54	4.09
Pll Shop Stock	2.05	4.82	2.80
Asl	3.13	4.05	3.97
Theater	24.89	26.71	29.77
Conus	2.50	0.00	0.00

LHX Outputs

Table 23

Average Time to Repair at Each Service Level - Utility

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)

Utility LHX-U

Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	1.31	0.00	2.79
PLL Shop Stock	2.23	9.24	3.01
Asl	3.16	0.00	4.15
Theater	26.21	0.00	26.83
Conus	0.00	0.00	0.00

Table 24

Average Time to Repair at Each Service Level - Floats

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)

Floats <=====> LHXS

Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	0.00	0.00	0.00
Pll Shop Stock	0.00	0.00	0.00
Asl	0.00	0.00	0.00
Theater	0.00	0.00	23.28
Conus	0.00	0.00	7.84

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)

Floats <=====> LHX-U

Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	0.00	0.00	0.00
Pll Shop Stock	0.00	0.00	0.00
Asl	0.00	0.00	0.00
Theater	0.00	0.00	25.96
Conus	0.00	0.00	0.00

Table 25

MOS Cumulative Statistics - Attack

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

ANC LVL1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	11	0	715.50	220.75	251.65	1187.90	11.67	12.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

ANC LVL1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	11	0	679.00	191.50	325.71	1196.21	10.67	11.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

ANC LVL1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	11	0	657.75	178.50	398.61	1234.86	10.25	11.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

ANC LVL2

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	8	7	6.25	0.50	0.00	6.75	0.08	1.00
66J	1	0	23.04	0.00	0.00	23.04	0.28	1.00
661	4	3	50.88	0.00	0.00	50.88	0.62	1.00
683	2	2	23.75	4.50	0.00	28.25	0.35	1.00
684	5	4	30.00	5.00	0.00	35.00	0.43	1.00
68G	2	1	10.00	2.50	0.00	12.50	0.15	1.00
68K	1	0	6.25	1.50	0.00	7.75	0.09	1.00
355	5	4	20.00	2.50	0.00	22.50	0.28	1.00

LHX Outputs

Table 26

MOS Cumulative Statistics - Recon

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

RECON SVC1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	10	0	571.00	238.75	308.05	1117.80	9.92	10.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

RECON SVC1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	10	0	473.00	235.00	281.77	989.77	8.68	9.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

RECON LVL2

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	5	5	3.75	1.00	0.00	4.75	0.06	1.00
66J	1	0	19.20	0.00	0.00	19.20	0.24	1.00
661	2	3	38.40	0.00	0.00	38.40	0.47	1.00
683	1	1	16.25	4.00	0.00	20.25	0.25	1.00
684	4	4	25.00	4.00	0.00	29.00	0.36	1.00
68G	1	1	15.00	1.00	0.00	16.00	0.20	1.00
68K	1	0	3.75	0.50	0.00	4.25	0.05	1.00
355	2	1	12.50	1.50	0.00	14.00	0.17	1.00

LHX Outputs

Table 27

MOS Cumulative Statistics - Utility

=============== MOS CUMULATIVE STATISTICS (Based on 8 Replications) ===================

==============================> UTIL LVL2 <======================================

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	3	3	1.25	1.00	0.00	2.25	0.03	1.00
661	1	0	0.96	0.00	0.00	0.96	0.01	1.00

=============== MOS CUMULATIVE STATISTICS (Based on 8 Replications) ===================

==============================> UTIL SVC1 <======================================

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
672	6	0	305.00	102.00	180.47	587.47	6.99	5.00

LHX Outputs

Table 28

MOS Cumulative Statistics - AMC

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

AMC LVL3

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
67Z	19	18	23.00	4.00	0.00	27.00	0.33	1.00
66J	1	0	62.48	0.00	0.00	62.48	0.77	1.00
66T	4	4	109.44	0.00	0.00	109.44	1.34	2.00
68B	6	5	43.75	6.50	0.00	50.25	0.62	1.00
68D	6	6	78.75	13.50	0.00	92.25	1.13	2.00
68G	2	2	28.75	6.50	0.00	35.25	0.43	1.00
68H	2	1	10.00	1.00	0.00	11.00	0.13	1.00
68K	1	0	13.75	2.00	0.00	15.75	0.19	1.00
35S	8	7	28.75	5.50	0.00	34.25	0.42	1.00

Predecessor Outputs

Table 29

Mission Frequency Count - Attack

MISSION FREQUENCY COUNT
FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS)
Weapon System OH-58 Mission Name = ANC MSN 1

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
7	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
6	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
5	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
4	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
3	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
2	.	.	87	.	.	.	.	.	.	.	.	.	87	45.3%
1	.	.	87	.	.	.	.	.	.	.	.	.	87	45.3%
0	.	.	18	.	.	.	.	.	.	.	.	.	18	9.4%
Column Total	0	0	192	0	0	0	0	0	0	0	0	0		
Percent	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

MISSION FREQUENCY COUNT
FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS)
Weapon System AH-1 Mission Name = ANC MSN 1

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
7	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
6	.	.	.	.	.	.	2	.	.	.	.	.	2	1.0%
5	.	.	.	.	.	2	25	.	.	.	.	.	27	14.1%
4	.	.	.	.	4	7	41	.	.	.	.	.	52	27.1%
3	.	.	.	1	7	18	43	.	.	.	.	.	69	35.9%
2	.	.	1	1	6	9	13	.	.	.	.	.	30	15.6%
1	.	.	.	.	2	2	6	.	.	.	.	.	10	5.2%
0	.	.	.	.	1	1	.	.	.	.	.	.	2	1.0%
Column Total	0	0	1	2	20	39	130	0	0	0	0	0		
Percent	0.0	0.0	0.5	1.0	10.4	20.3	67.7	0.0	0.0	0.0	0.0	0.0		

Predecessor Outputs

Table 30

Mission Frequency Count - Recon 1

MISSION FREQUENCY COUNT
FOR EIGHT REPLICATIONS (TOTAL = 120 MISSIONS)
Weapon System OH-58 — Mission Name = Recon 1

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
7	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
6	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
5	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
4	.	.	.	.	10	.	.	.	.	.	.	.	10	8.3%
3	.	.	.	6	27	.	.	.	.	.	.	.	33	27.5%
2	.	.	13	10	14	.	.	.	.	.	.	.	37	30.8%
1	.	6	6	17	8	.	.	.	.	.	.	.	37	30.8%
0	.	.	2	1	.	.	.	.	.	.	.	.	3	2.5%
Column Total	0	6	21	34	59	0	0	0	0	0	0	0		
Percent	0.0	5.0	17.5	28.3	49.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

MISSION FREQUENCY COUNT
FOR EIGHT REPLICATIONS (TOTAL = 120 MISSIONS)
Weapon System AH-1 — Mission Name = Recon 1

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
7	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
6	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
5	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
4	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
3	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
2	.	.	39	.	.	.	.	.	.	.	.	.	39	32.5%
1	.	4	45	.	.	.	.	.	.	.	.	.	49	40.8%
0	5	5	22	.	.	.	.	.	.	.	.	.	32	26.7%
Column Total	5	9	106	0	0	0	0	0	0	0	0	0		
Percent	4.2	7.5	88.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

Predecessor Outputs

Table 31

Mission Frequency Count - Recon 2

MISSION FREQUENCY COUNT
FOR EIGHT REPLICATIONS (TOTAL = 96 MISSIONS)
Weapon System OH-58 Mission Name = Recon 2
AIRCRAFT | NUMBER OF AIRCRAFT STARTING

COMPLETING	0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
7	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
6	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
5	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
4	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
3	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
2	.	.	43	.	.	.	.	.	.	.	.	.	43	44.8%
1	.	10	32	.	.	.	.	.	.	.	.	.	42	43.8%
0	4	.	7	.	.	.	.	.	.	.	.	.	11	11.5%
Column Total	4	10	82	0	0	0	0	0	0	0	0	0		
Percent	4.2	10.4	85.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

MISSION FREQUENCY COUNT
FOR EIGHT REPLICATIONS (TOTAL = 96 MISSIONS)
Weapon System AH-1 Mission Name = Recon 2
AIRCRAFT | NUMBER OF AIRCRAFT STARTING

COMPLETING	0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
7	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
6	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
5	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
4	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
3	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
2	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
1	.	51	.	.	.	.	.	.	.	.	.	.	51	53.1%
0	4	41	.	.	.	.	.	.	.	.	.	.	45	46.9%
Column Total	4	92	0	0	0	0	0	0	0	0	0	0		
Percent	4.2	95.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

Predecessor Outputs

Table 32

Mission Frequency Count - Utility

MISSION FREQUENCY COUNT
FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS)
Weapon System OH-58 === Mission Name = Utility

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11	totl	perc
11	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
10	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
9	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
8	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
7	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
6	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
5	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
4	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
3	.	.	.	58	.	.	.	.	.	.	.	.	58	30.2%
2	.	.	3	76	.	.	.	.	.	.	.	.	79	41.1%
1	.	3	1	44	.	.	.	.	.	.	.	.	48	25.0%
0	1	.	2	4	.	.	.	.	.	.	.	.	7	3.6%
Column Total	1	3	6	182	0	0	0	0	0	0	0	0		
Percent	0.5	1.6	3.1	94.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

Predecessor Outputs

Table 33

Average Flying Time Per Acft Launched - Attack

================== AVERAGE FLYING TIME PER ACFT LAUNCHED ========================
=========================== FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS) =======
=== Weapon System OH-58 === Mission Name = ANC MSN 1 ================================
=== AIRCRAFT === | ========== NUMBER OF AIRCRAFT STARTING ========================

COMPLETING	0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.	.	.	.	.	.
3	.	.	.	.	.	.	.	.	.	.	.	.
2	.	.	3.00	.	.	.	.	.	.	.	.	.
1	.	.	2.30	.	.	.	.	.	.	.	.	.
0	.	.	1.24	.	.	.	.	.	.	.	.	.

Average mission time = 2.52

================== AVERAGE FLYING TIME PER ACFT LAUNCHED ========================
=========================== FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS) =======
=== Weapon System AH-1 === Mission Name = ANC MSN 1 ================================
=== AIRCRAFT === | ========== NUMBER OF AIRCRAFT STARTING ========================

COMPLETING	0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	3.00	.	.	.	.	.
5	.	.	.	.	.	3.00	2.71	.	.	.	.	.
4	.	.	.	.	3.00	2.71	2.49	.	.	.	.	.
3	.	.	.	3.00	2.52	2.37	2.16	.	.	.	.	.
2	.	.	3.00	2.41	2.04	2.32	1.86	.	.	.	.	.
1	.	.	.	.	2.21	1.58	1.54	.	.	.	.	.
0	.	.	.	.	1.00	1.24	.	.	.	.	.	.

Average mission time = 2.35

Table 34

Average Flying Time Per Acft Launched - Recon 1

AVERAGE FLYING TIME PER ACFT LAUNCHED
FOR EIGHT REPLICATIONS (TOTAL = 120 MISSIONS)
Weapon System CH-53 Mission Name = Recon 1

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	-	3.00	.	.	.	.	.	.	.
3	.	.	-	3.00	2.58	.	.	.	.	.	.	.
2	.	-	3.00	2.36	2.25	.	.	.	.	.	.	.
1	-	3.00	2.45	1.95	1.82	.	.	.	.	.	.	.
0	.	-	1.55	1.67	.	.	.	.	.	.	.	.

Average mission time = 2.47

AVERAGE FLYING TIME PER ACFT LAUNCHED
FOR EIGHT REPLICATIONS (TOTAL = 120 MISSIONS)
Weapon System AH-1 Mission Name = Recon 1

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.	.	.	.	.	.
3	.	.	.	.	.	.	.	.	.	.	.	.
2	.	-	3.00	.	.	.	.	.	.	.	.	.
1	-	3.00	2.23	.	.	.	.	.	.	.	.	.
0	0.00	1.87	1.47	.	.	.	.	.	.	.	.	.

Average mission time = 2.26

Predecessor Outputs

Table 35

Average Flying Time Per Acft Launched - Recon 2

AVERAGE FLYING TIME PER ACFT LAUNCHED

FOR EIGHT REPLICATIONS (TOTAL = 96 MISSIONS)

Weapon System OH-58 Mission Name = Recon 2

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.	.	.	.	.	.
3	.	.	.	.	.	.	.	.	.	.	.	.
2	.	.	3.00	.	.	.	.	.	.	.	.	.
1	.	3.00	2.25	.	.	.	.	.	.	.	.	.
0	0.00	.	1.55	.	.	.	.	.	.	.	.	.

Average mission time = 2.52

AVERAGE FLYING TIME PER ACFT LAUNCHED

FOR EIGHT REPLICATIONS (TOTAL = 96 MISSIONS)

Weapon System AH-1 Mission Name = Recon 2

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.	.	.	.	.	.
3	.	.	.	.	.	.	.	.	.	.	.	.
2	.	.	.	.	.	.	.	.	.	.	.	.
1	.	3.00	.	.	.	.	.	.	.	.	.	.
0	0.00	1.54	.	.	.	.	.	.	.	.	.	.

Average mission time = 2.25

Table 36

Average Flying Time Per Acft Launched - Utility

AVERAGE FLYING TIME PER ACFT LAUNCHED

FOR EIGHT REPLICATIONS (TOTAL = 192 MISSIONS)

Weapon System OH-58 === Mission Name = Utility

AIRCRAFT COMPLETING	NUMBER OF AIRCRAFT STARTING 0	1	2	3	4	5	6	7	8	9	10	11
11	.	.	.	.	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.	.	.	.	.	.
3	.	.	.	3.00	.	.	.	.	.	.	.	.
2	.	.	3.00	2.45	.	.	.	.	.	.	.	.
1	.	3.00	2.18	2.00	.	.	.	.	.	.	.	.
0	0.00	.	1.57	1.45	.	.	.	.	.	.	.	.

Average mission time = 2.48

Predecessor Outputs

Table 37

Aircraft Hours Per Day at Each Service Level - Attack

Aircraft Hours Per Day at Each Service Level

Attack — OH-58

Category	Process Time
On Flight Line	2.4282
Flight Line to NSC	0.0104
At NSC	1.7417
Flight Line to AMC	0.1111
At AMC	3.9103
AMC to Flight Line	0.0590
NSC to Flight Line	0.0104

Aircraft Hours Per Day at Each Service Level

Attack — AH-1

Category	Process Time
On Flight Line	2.4705
Flight Line to NSC	0.0635
At NSC	6.7908
Flight Line to AMC	0.1657
At AMC	4.2625
AMC to Flight Line	0.0833
NSC to Flight Line	0.0625

Predecessor Outputs

Table 38

Aircraft Hours Per Day at Each Service Level - Recon

Aircraft Hours Per Day at Each Service Level

Recon OH-58

Category	Process Time
On Flight Line	1.9532
Flight Line to NSC	0.0313
At NSC	2.6889
Flight Line to AMC	0.1684
At AMC	11.6913
AMC to Flight Line	0.0903
NSC to Flight Line	0.0313

Aircraft Hours Per Day at Each Service Level

Recon AH-1

Category	Process Time
On Flight Line	3.3337
Flight Line to NSC	0.0521
At NSC	3.2395
Flight Line to AMC	0.1432
At AMC	5.6004
AMC to Flight Line	0.0729
NSC to Flight Line	0.0495

Predecessor Outputs

Table 39

Aircraft Hours Per Day at Each Service Level - Utility

Aircraft Hours Per Day at Each Service Level

Utility — OH-58

Category	Process Time
On Flight Line	2.1864
Flight Line to NSC	0.0174
At NSC	4.1500
Flight Line to AMC	0.3125
At AMC	2.6202
AMC to Flight Line	0.1701
NSC to Flight Line	0.0174

Predecessor Outputs

Table 40

Aircraft Hours Per Day at Each Service Level - Floats

Aircraft Hours Per Day at Each Service Level

Floats OH-58

Category	Process Time
On Flight Line	0.0000
Flight Line to NSC	0.0000
At NSC	0.0000
Flight Line to AMC	0.0000
At AMC	68.5975
AMC to Flight Line	0.0104
NSC to Flight Line	0.0000

Aircraft Hours Per Day at Each Service Level

Floats AH-1

Category	Process Time
On Flight Line	0.0000
Flight Line to NSC	0.0000
At NSC	0.0000
Flight Line to AMC	0.0000
At AMC	26.2157
AMC to Flight Line	0.0208
NSC to Flight Line	0.0000

Table 41

Frequency of Repair - Attack

FREQUENCY OF REPAIR (Eight Replications)

Attack =====> OH-58

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	109	4	23	0
PLL Shop Stock	31	2	10	0
ASL	8	0	1	0
Theater	5	0	3	0
Conus	1	0	0	0
TOTAL	154	6	37	0
Percent of Total	78.2%	3.0%	18.8%	0.0%

Total Repairs = 197

FREQUENCY OF REPAIR (Eight Replications)

Attack =====> AH-1

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	373	52	57	0
PLL Shop Stock	95	8	22	0
ASL	34	1	6	0
Theater	20	4	2	0
Conus	1	0	0	0
TOTAL	523	65	87	0
Percent of Total	77.5%	9.6%	12.9%	0.0%

Total Repairs = 675

Predecessor Outputs

Table 42

Frequency of Repair - Recon

FREQUENCY OF REPAIR (Eight Replications)

Recon <====> OH-58

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	234	15	41	0
Pll Shop Stock	62	1	5	0
Asl	24	2	1	0
Theater	10	0	3	0
Conus	1	0	2	0
TOTAL	331	18	52	0
Percent of Total	82.5%	4.5%	13.0%	0.0%

Total Repairs = 401

FREQUENCY OF REPAIR (Eight Replications)

Recon <====> AH-1

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	143	15	19	0
Pll Shop Stock	36	4	5	0
Asl	14	0	3	0
Theater	7	1	1	0
Conus	1	0	0	0
TOTAL	201	20	28	0
Percent of Total	80.7%	8.0%	11.2%	0.0%

Total Repairs = 249

Predecessor Outputs

Table 43

Frequency of Repair - Utility

FREQUENCY OF REPAIR (Eight Replications)

Utility <====> CH-58

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	118	4	38	0
Pll Shop Stock	27	1	4	0
Asl	10	0	7	0
Theater	7	0	1	0
Conus	0	0	0	0
TOTAL	162	5	50	0
Percent of Total	74.7%	2.3%	23.0%	0.0%

Total Repairs = 217

Predecessor Outputs

Table 44

Frequency of Repair - Floats

FREQUENCY OF REPAIR (Eight Replications)

Floats <====> OH-58

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	0	0	0	0
Pll Shop Stock	0	0	0	0
Asl	0	0	0	0
Theater	0	0	2	0
Conus	0	0	2	0
TOTAL	0	0	4	0
Percent of Total	0.0%	0.0%	100.0%	0.0%

Total Repairs = 4

FREQUENCY OF REPAIR (Eight Replications)

Floats <====> AH-1

Parts From	Flight Line	Level 2 Service	Lvl 3 Svc (AMC)	Level 4 Service
No Parts	0	0	0	0
Pll Shop Stock	0	0	0	0
Asl	0	0	0	0
Theater	0	0	7	0
Conus	0	0	0	0
TOTAL	0	0	7	0
Percent of Total	0.0%	0.0%	100.0%	0.0%

Total Repairs = 7

Predecessor Outputs

Table 45

Average Time to Repair at Each Service Level - Attack

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)

Attack OH-58

Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	0.86	1.41	1.76
Pll Shop Stock	1.85	2.40	2.15
Asl	2.89	0.00	3.60
Theater	23.64	0.00	26.67
Conus	81.30	0.00	0.00

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)

Attack AH-1

Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	1.16	3.65	3.63
Pll Shop Stock	2.11	4.26	3.91
Asl	3.13	4.03	3.91
Theater	23.84	29.97	32.93
Conus	76.75	0.00	0.00

Predecessor Outputs

Table 46

Average Time to Repair at Each Service Level - Recon

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)

Recon OH-58

Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	0.85	2.73	1.88
Pll Shop Stock	1.76	2.15	2.89
Asl	2.82	2.67	3.15
Theater	26.41	0.00	25.83
Conus	26.35	0.00	217.80

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)

Recon AH-1

Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	1.13	3.17	6.84
Pll Shop Stock	2.16	2.26	6.61
Asl	3.13	0.00	6.96
Theater	24.01	8.25	26.83
Conus	218.25	0.00	0.00

Predecessor Outputs

Table 47

Average Time to Repair at Each Service Level - Utility

====================== AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications) ===

==========================> Utility <====> OH-58 <==================================

===== Parts From =====	=== Flight Line ===	=== Level 2 Service ===	=== Level 3 Service ===
No Parts	0.90	3.92	1.92
Pll Shop Stock	1.91	5.07	2.40
Asl	2.92	0.00	3.39
Theater	23.86	0.00	24.63
Conus	0.00	0.00	0.00

Predecessor Outputs

Table 48

Average Time to Repair at Each Service Level - Floats

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)

Floats <====> CH-58

Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	0.00	0.00	0.00
Pll Shop Stock	0.00	0.00	0.00
Asl	0.00	0.00	0.00
Theater	0.00	0.00	25.29
Conus	0.00	0.00	111.90

AVERAGE TIME TO REPAIR AT EACH SERVICE LEVEL (Eight Replications)

Floats <====> AH-1

Parts From	Flight Line	Level 2 Service	Level 3 Service
No Parts	0.00	0.00	0.00
Pll Shop Stock	0.00	0.00	0.00
Asl	0.00	0.00	0.00
Theater	0.00	0.00	26.22
Conus	0.00	0.00	0.00

Predecessor Outputs

Table 49

MOS Cumulative Statistics - Attack

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

ANC SVC1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
67V	6	0	221.00	69.00	100.68	370.68	3.31	6.00
67Y	7	0	498.00	143.25	218.04	859.29	7.86	8.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

ANC SVC1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
67V	6	0	220.55	53.50	39.27	313.32	3.36	6.00
67Y	7	0	490.00	155.50	293.55	939.05	7.91	8.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

ANC SVC1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
67V	6	0	218.20	41.50	29.51	289.21	3.18	6.00
67Y	7	0	443.00	145.50	274.61	863.11	7.21	8.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications)

ANC LVL2

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
67V	5	4	0.70	0.00	0.00	0.70	0.01	1.00
67Y	8	8	3.00	0.00	0.00	3.00	0.04	1.00
66V	1	1	4.75	0.00	0.00	4.75	0.06	1.00
66Y	2	2	23.04	0.00	0.00	23.04	0.28	1.00
66J	1	0	54.76	0.00	0.00	54.76	0.67	1.00
68B	1	1	2.00	0.50	0.00	2.50	0.03	1.00
68D	1	1	6.40	1.00	0.00	7.40	0.09	1.00
68F	1	0	0.00	0.00	0.00	0.00	0.00	0.00
68G	2	1	4.00	1.00	0.00	5.00	0.06	1.00
68J	4	4	33.25	3.50	0.00	36.75	0.45	1.00
68K	1	0	0.00	0.00	0.00	0.00	0.00	0.00
68M	4	3	9.00	0.50	0.00	9.50	0.12	1.00
35K	5	4	9.10	1.00	0.00	10.10	0.12	1.00

Predecessor Outputs

Table 50

MOS Cumulative Statistics - Recon

MOS CUMULATIVE STATISTICS (Based on 8 Replications) — RECON SVC1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
67V	6	0	281.80	117.25	534.79	933.84	6.89	5.00
67Y	4	0	212.00	68.25	89.59	369.84	3.63	6.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications) — RECON SVC1

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
67V	6	0	313.00	175.25	156.82	645.07	5.98	6.00
67Y	4	0	234.75	105.50	165.98	506.23	4.17	5.00

MOS CUMULATIVE STATISTICS (Based on 8 Replications) — RECON LVL2

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
67V	1	3	4.20	0.50	0.00	4.70	0.06	1.00
67Y	4	4	4.00	1.00	0.00	5.00	0.06	1.00
66V	1	1	11.40	0.00	0.00	11.40	0.14	1.00
66Y	1	1	5.12	0.00	0.00	5.12	0.06	1.00
66J	1	1	14.08	0.00	0.00	14.08	0.17	1.00
68B	1	0	1.00	0.00	0.00	1.00	0.01	1.00
68D	1	0	2.40	0.00	0.00	2.40	0.03	1.00
68G	1	1	6.30	1.00	0.00	7.30	0.09	1.00
68J	2	2	7.00	1.00	0.00	8.00	0.10	1.00
68K	1	0	0.00	0.00	0.00	0.00	0.00	0.00
68M	1	1	4.00	0.00	0.00	4.00	0.05	1.00
35K	2	2	2.95	0.50	0.00	3.45	0.04	1.00

Predecessor Outputs

Table 51

MOS Cumulative Statistics - Utility

================ MOS CUMULATIVE STATISTICS (Based on 8 Replications) ====================

================================> UTIL LVL2 <==

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
67V	1	0	3.50	0.50	0.00	4.00	0.05	1.00
66V	2	0	0.00	0.00	0.00	0.00	0.00	0.00

================ MOS CUMULATIVE STATISTICS (Based on 8 Replications) ====================

================================> UTIL SVC1 <==

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
67V	6	0	307.45	147.50	167.40	622.35	5.58	6.00

Predecessor Outputs

Table 52

MOS Cumulative Statistics - AMC

=============== MOS CUMULATIVE STATISTICS (Based on 8 Replications) ====================

================================> AMC LVL3 <==

MOS	SHIFT1	SHIFT2	Direct	Indir	Other	Total	Wkld Rqd	Strength
67V	5	5	8.15	2.50	0.00	10.65	0.13	1.00
67Y	6	6	7.00	0.50	0.00	7.50	0.09	1.00
66V	1	1	120.70	0.00	0.00	120.70	1.48	2.00
66Y	1	1	75.52	0.00	0.00	75.52	0.93	1.00
66J	1	0	67.56	0.00	0.00	67.56	0.83	1.00
67T	1	0	0.00	0.00	0.00	0.00	0.00	0.00
68B	4	4	2.40	0.50	0.00	2.90	0.04	1.00
68D	3	2	20.50	4.00	0.00	24.50	0.30	1.00
68F	3	3	0.00	0.00	0.00	0.00	0.00	0.00
68G	3	2	12.80	1.00	0.00	13.80	0.17	1.00
68H	2	1	5.40	1.50	0.00	6.90	0.08	1.00
68J	2	2	36.75	6.00	0.00	42.75	0.52	1.00
68K	1	0	0.00	0.00	0.00	0.00	0.00	0.00
68M	2	2	15.00	3.50	0.00	18.50	0.23	1.00
35K	1	1	31.70	4.50	0.00	36.20	0.44	1.00
35L	2	2	19.40	4.50	0.00	23.90	0.29	1.00
35M	2	2	13.20	2.50	0.00	15.70	0.19	1.00
35P	2	1	0.00	0.00	0.00	0.00	0.00	0.00
35R	2	1	42.05	7.00	0.00	49.05	0.60	1.00

EAM Model Instructions

Introduction

The EAM model integrates the possible BIT failures into the Administrative and Logistic Delay Time (ALDT) model from the published LHX RAM Rationale Report. It uses the AH-64 BIT failure data as the base case to determine the sensitivity of LHX mission capability to changes in BIT performance by incrementally improving the values of BIT performance and re-running the model.

Hardware and Software Requirements

The EAM model requires an IBM personal computer or compatible to run. It employs off the shelf software, Lotus 1-2-3, Version 2.0 or higher. The computer used to run EAM must be equipped with an operating system which will run the selected version of Lotus 1-2-3. In order to output data from the EAM model a printer must be available and configured to print Lotus 1-2-3 files.

Getting Started

In order to invoke the EAM model, the user must first load Lotus 1-2-3. Lotus 1-2-3 can be loaded from either a floppy drive or hard disk. Once Lotus has been loaded, the user must then load the EAM spreadsheet. This is accomplished by placing the floppy disk labelled EAM into the system's floppy drive. Next, change the default drive in Lotus to the drive in which the spreadsheet file is stored and load the model by executing the steps listed below.[3]

SELECT OPTION	ACTION
FILE	To invoke the 1st order File options menu
DIRECTORY	To change the logged directory
B:\	To change the current directory to B:\
<RETURN>	RETURN

---

[3]This tutorial assumes that the disk containing the EAM model is located in the floppy disk drive designated as B:. Appropriate substitutions should be made according to the the designation of the disk drives of the system being used.

SELECT OPTION	ACTION
FILE	To invoke the 1st order File options menu
RETRIEVE	To load the EAM worksheet file
EAM	To load EAM
<RETURN>	RETURN

The EAM spreadsheet is a very large spreadsheet (34x249) and therefore it will take several minutes to load the EAM model and for it to appear. At any point, the user may return to a previous menu option by hitting the <Esc> key. The <Esc> key will only return to the next higher level menu. Therefore it may be necessary to hit the key several times in order to return to the main menu. Once the model is loaded, the user may invoke the main menu by typing the "/" key.

To save and exit from the EAM model and Lotus, the user should follow the prescribed Lotus procedures to save and exit the program. It is important to remember that if any changes have been made to the model, the user must save the file under a name other than EAM in order to keep the original model intact. Listed below are the steps required to rename and save the EAM model.

SELECT OPTION	ACTION
/	To invoke the top line menu
FILE	To invoke the 1st order File options menu
SAVE	To save the changes to the EAM model
EAM1	To rename the model from its original name of EAM[4]

[4]Since the EAM model is a large spreadsheet, the user should make sure there is sufficient room on the floppy disk on which the renamed model is being saved. If there is not sufficient room, the user may save it to another floppy disk by inserting a new disk or changing the location of the drive to which the file will be saved.

Using The EAM Model

The EAM model is a spreadsheet set up with the events and data elements in the rows and excursions represented in the columns. Each of the four excursions listed below are contained in the model and represent the two types of factors (failure mode and down time) investigated by the model.

BIT Cannot Locate
Isolation Error
False Indication
Depot Maintenance Time
Depot Transit Time

The first two data columns of the spreadsheet show the values for BIT that performs according to specification and for the AH-64 base case. The remaining columns display the impact of incremental increases in the value of BIT performance for each excursion. The headings for the remainder of the columns indicate the value of the factor that was varied in the excursion. The labels in the extreme left hand column correspond to a decision point, process, or dummy operation of the model.

Since the model employs Lotus 1-2-3 it uses Lotus commands to move through the spreadsheet, to change cell entries, and to print the model. For further information regarding the use of Lotus commands, consult your Lotus user's manual.

Inputs. Table 53 displays the input variables for EAM and their initial values. The inputs are based upon the AH-64 BIT failure data collected from Fort Rucker, AL, and Fort Hood, TX, in 1985 and 1986, the LHX RAM data, and the ALDT model parameters. Table 54 provides a description of the parameters that were varied in each excursion to determine the impact of various BIT failures on aircraft availability, probability of depot maintenance, maintenance time and total down time for depot maintenance, the maintenance ratio, and the total down time associated with each discreet path of the model.

The remaining variables reflect the probabilities and delays associated with the LHX ALDT Model as specified in the LHX RAM Rationale Report. As more reliable information for the LHX becomes available, the values of the variables can be adjusted to more accurately reflect the performance of the LHX. This is accomplished by simply moving the cursor to the desired cell and retyping the value of the cell. Remember to change the name of the spreadsheet when saving the model in order to keep the changes as well as the original version of the model.

Outputs. The outputs of the model are given by looking across the spreadsheet to examine the changes in the data

Table 53

EAM Model Inputs

VARIABLE	PERFECT BIT	AH-64 BASE
CAN ISOLATE	1.0000	0.9400
HARDWARE OK	1.0000	0.9500
INDICATES GO	1.0000	0.9200
DEPOT TRANS TIME	8.0000	8.0000
DEPOT MAINT	3.1500	3.1500
BIT APPLIES	0.9500	0.9500
FLT LIN REPAIR	0.8000	0.8000
NEED PART	0.3000	0.3000
MAINT ACTION	0.5000	0.5000
GO TO HSC	0.5000	0.5000
RETURN TO FLT LN	0.3000	0.3000
PART ON PLL	0.8500	0.8500
GO TO AMC	0.5000	0.5000
PART ON ASL	0.9500	0.9500
IN STK ASL	0.8500	0.8500
RTN TO ACFT	0.5000	0.5000
GO TO PLL STOCK	0.3000	0.3000
IN STK PLL	0.8000	0.8000
CONTROL SUB	0.1000	0.1000
GO TO ACFT	0.3000	0.3000
REMOVE PART	0.3000	0.3000
RTN TO ACFT	0.6000	0.6000
THEATER SEARCH	24.0000	24.0000
PART IN THEATER	0.8000	0.8000
PART TO AMC	96.0000	96.0000
REQ FROM CONUS	840.0000	840.0000
BIT APPLIES	0.9500	0.9500
FLYING HOURS	480.0000	480.0000
MTBEMA	4.5000	4.5000
ELAPSED HOURS	168.0000	168.0000
ACFT ASSIGNED	11.0000	11.0000

Table 54

EAM Parameters

	EXCURSION	VARIABLE	DEFINITION
1.	BIT CANNOT LOCATE	CAN ISOLATE	Probability that BIT can successfully isolate the fault to a LRU
2.	ISOLATION ERROR	INDICATES GO	Probability that BIT indicates that an identified fault has been corrected
		INDICATES GO	Probability that BIT indicates that an identified fault has been corrected
3.	FALSE INDICATION	HARDWARE OK	Probability that the hardware functions properly given that BIT indicates that the fault has been corrected
4.	DEPOT MAINT TIME	DEPOT MAINT	Direct mean maintenance man hours (MMMH) to repair a fault
5.	DEPOT TRAN TIME	DEPOT TRANS TIME	Delay time associated with going to and from the Depot

elements as one of the factors, failure mode or down time, is varied. For example, Figure 1 depicts the results of the analysis investigating the impact of BIT failures on the Aircraft Availability (A_o). The top three graphs illustrate the impact of the three BIT failure modes while the bottom two illustrate the impact of down time on A_o.

Changing EAM Model Variables. The input variables of EAM are changed by simply moving the cursor to the appropriate spreadsheet cell and retyping the value of the cell. When the cell value is changed, the affected formulas will be updated. If

the user wishes to save his changes, he must change the name of the file when saving the spreadsheet. This is accomplished by executing the steps discussed in Section 2.0.

Printing Outputs of EAM

Hard copy output of the EAM model can be obtained in two ways. The user may use the Lotus print commands to specify the range to be printed and send it directly to a printer or he may specify the range to be printed and save it as a print file. The Lotus 1-2-3 Users Manual provides specific directions for printing Lotus 1-2-3 files. If the user selects to save the file to a print file, the file will be given a file extension ".PRN". The user may then use a word processing package to format and display the data as he wishes.

Software and Model Formulas

The following pages contain a description of the cell entries used in the EAM model. Each formula is defined in terms of cell entries as well as descriptive names. Those cells that are inputs to the model are denoted as such. The values of these cells can be found in Table 54 as provided previously.

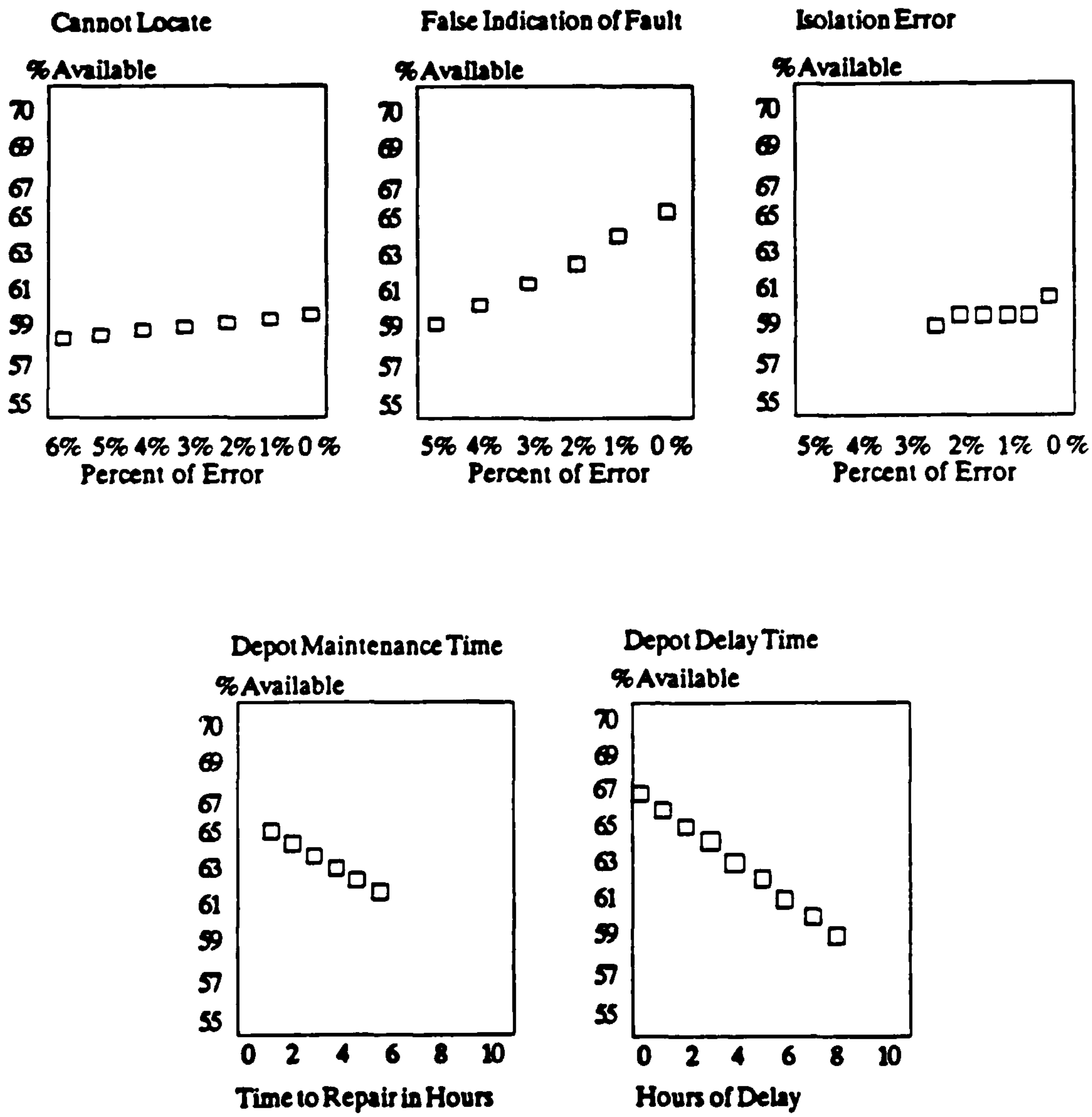


Figure 1. Sensitivity of aircraft availability to BIT performance.

EAM Formulas

<u>EVENT/EXCURSION</u> = COLUMN/ROW HEADING
<u>CAN ISOLATE</u> = INPUT
<u>HARDWARE OK</u> = INPUT
<u>INDICATES GO</u> = INPUT
<u>DEPOT TRANS TIME</u> = INPUT
<u>DEPOT MAINT</u> = INPUT
<u>BIT APPLIES</u> = INPUT
<u>FLT LN REPAIR</u> = INPUT
<u>NEED PART</u> = INPUT
<u>MAINT ACTION</u> = INPUT
<u>GO TO HSC</u> = INPUT
<u>RETURN TO FLT LN</u> = INPUT
<u>PART ON PLL</u> = INPUT
<u>GO TO AMC</u> = INPUT
<u>PART ON ASL</u> = INPUT
<u>IN STK ASL</u> = INPUT
<u>RTN TO ACFT</u> = INPUT
<u>GO TO PLL STOCK</u> = INPUT
<u>IN STK PLL</u> = INPUT
<u>CONTROL SUB</u> = INPUT
<u>GO TO ACFT</u> = INPUT
<u>REMOVE PART</u> = INPUT
<u>RTN TO OWN ACFT</u> = INPUT
<u>THEATER SEARCH</u> = INPUT
<u>PART IN THEATER</u> = INPUT
<u>PART TO AMC</u> = INPUT
<u>REQ FROM CONUS</u> = INPUT
<u>BIT APPLIES</u> = INPUT
<u>FLYING HOURS</u> = INPUT
<u>MTBEMA</u> = INPUT
<u>ELAPSED HOURS</u> = INPUT
<u>ACFT ASSIGNED</u> = INPUT

<u>PROB OF DEPOT</u> = PROB DEPOT 1 + PROB DEPOT 2 + PROB DEPOT 3 + PROB DEPOT 4 + PROB DEPOT 5 + PROB DEPOT 6 + PROB DEPOT 7 + PROB DEPOT 8 + PROB DEPOT 9 + PROB DEPOT 10 + PROB DEPOT 11 + PROB DEPOT 12 + PROB DEPOT 13 + PROB DEPOT 14 + PROB DEPOT 15
<u>B13</u> = B27 + B35 + B43 + B51 + B59 + B67 + B75 + B83 + B91 + B99 + B107 + B115 + B123 + B131 + B139

<u>TOTAL DEPOT</u> = TRANS DEPOT 1 + TRANS DEPOT 2 + TRANS DEPOT 3 + TRANS DEPOT 4 + TRANS DEPOT 5 + TRANS DEPOT 6 + TRANS DEPOT 7 + TRANS DEPOT 8 + TRANS DEPOT 9 + TRANS DEPOT 10 + TRANS DEPOT 11 + TRANS DEPOT 12 + TRANS DEPOT 13 + TRANS DEPOT 14 + TRANS DEPOT 15
<u>B15</u> = B29 + B37 + B45 + B53 + B61 + B69 + B77 + B85 + B93 + B101 + B109 + B117 + B125 + B133 + B141

TOTAL DEPOT MAINT = MAINT DEPOT 1 + MAINT DEPOT 2 + MAINT DEPOT 3 + MAINT DEPOT 4 + MAINT DEPOT 5 + MAINT DEPOT 6 + MAINT DEPOT 7 + MAINT DEPOT 8 + MAINT DEPOT 9 + MAINT DEPOT 10 + MAINT DEPOT 11 + MAINT DEPOT 12 + MAINT DEPOT 13 + MAINT DEPOT 14 + MAINT DEPOT 15
B17 = B31 + B39 + B47 + B55 + B63 + B71 + B79 + B87 + B95 + B103 + B111 + B119 + B127 + B135 + B143

TOTAL DEPOT TIME = TOT DEPOT TRANS + TOT DEPOT MAINT
B19 = B15 + B17

MTTR = (PROB DEPOT 1*TOTAL DEPOT 1) + ((PROB OF DEPOT-PROB DEPOT 1)*(TOTAL DEPOT 1 + MAINT ACTION)) + (1-PROB OF DEPOT)*MAINT ACTION
B21 = (B27*B33) + ((B13-B27)*(B33 + B191)) + (1-B13)*B191

AVERAGE DOWN TIME = (TOTAL DEPOT TIME + TIME FLT LN RPR + TIME PART FROM PLL + TIME PART FROM ASL + TIME PART THEAT + TIME PART CONUS + TIME CNTROL SUB + TIME HSC W/O PART)
B23 = B19 + B149 + B153 + B157 + B161 + B165 + B169 + B239

AVAILABILITY = 100*(1-((FLYING HRS/MTBEMA)*AVG DOWN TIME)/(ELAPSED HRS*ACFT DENSITY))
B25 = 100*(1-((B243/B245)*B23)/(B247*B249))

PROB DEPOT 1 = BIT APPLIES*(1-CAN ISOLATE)
B27 = B185*(1-B3)

TRANS DEPOT 1 = PROB DEPOT 1*DEPOT TRANS TIME
B29 = B27*B9

MAINT DEPOT 1 = PROB DEPOT 1*DEPOT MAINT
B31 = + B27*B11

TOTAL DEPOT 1 = TRANS DEPOT 1 + MAINT DEPOT 1
B33 = B29 + B31

PROB DEPOT 2 = PROB 1*FLT LN REPAIR*(1-NEED PART)*PROB 3
B35 = B171*B187*(1-B189)*B175

TRANS DEPOT 2 = PROB DEPOT 2*DEPOT TRANS TIME
B37 = B35*B9

MAINT DEPOT 2 = PROB DEPOT 2*(DEPOT MAINT + MAINT ACTION)
B39 = B35*(B11 + B191)

TOTAL DEPOT 2 = TRANS DEPOT 2 + MAINT DEPOT 2
B41 = B37 + B39

PROB DEPOT 3 = PROB 1*FLT LN REPAIR*(1-NEED PART)*PROB 4
B43 = B171*B187*(1-B189)*B177

TRANS DEPOT 3 = PROB DEPOT 3*DEPOT TRANS TIME
B45 = B43*B9

MAINT DEPOT 3 = PROB DEPOT 3*(DEPOT MAINT + MAINT ACTION)
B47 = B43*(B11 + B191)

TOTAL DEPOT 3 = TRANS DEPOT 3 + MAINT DEPOT 3
B49 = B45 + B47

PROB DEPOT 4 = PROB 2*PROB 3
B51 = B173*B175

TRANS DEPOT 4 = PROB DEPOT 4*(DEPOT TRANS TIME + GO TO HSC)
B53 = B51*(B9 + B193)

MAINT DEPOT 4 = PROB DEPOT 4*(MAINT ACTION + DEPOT MAINT)
B55 = B51*(B191 + B11)

TOTAL DEPOT 4 = MAINT DEPOT 4 + TRANS DEPOT 4
B57 = B55 + B53

PROB DEPOT 5 = PROB 2*PROB 4
B59 = B173*B177

TRANS DEPOT 5 = PROB DEPOT 5*(GO TO HSC + DEPOT TRANS TIME)
B61 = B59*(B193 + B9)

MAINT DEPOT 5 = PROB DEPOT 5*(MAINT ACTION + DEPOT MAINT)
B63 = B59*(B191 + B11)

TOTAL DEPOT 5 = TRANS DEPOT 5 + MAINT DEPOT 5
B65 = B61 + B63

PROB DEPOT 6 = PROB 6*PART ON ASL*IN STK ASL* PROB 3
B67 = B181*B201*B203*B175

TRANS DEPOT 6 = PROB DEPOT 6*(AVERAGE TIME 1 + GO TO AMC + RTN TO ACFT + DEPOT TRANS TIME)
B69 = B67*(B229 + B199 + B205 + B9)

MAINT DEPOT 6 = PROB DEPOT 6*(MAINT ACTION + DEPOT MAINT)
B71 = B67*(B191 + B11)

TOTAL DEPOT 6 = TRANS DEPOT 6 + MAINT DEPOT 6
B73 = B69 + B71

PROB DEPOT 7 = PROB 6*PART ON ASL*IN STK ASL* PROB 4
B75 = B181*B201*B203*B177

TRANS DEPOT 7 = PROB DEPOT 7*(AVERAGE TIME 1 + GO TO AMC + RTN TO ACFT + DEPOT TRANS TIME)
B77 = B75*(B229 + B199 + B205 + B9)

MAINT DEPOT 7 = PROB DEPOT 7*(MAINT ACTION + DEPOT MAINT)
B79 = B75*(B191 + B11)

TOTAL DEPOT 7 = TRANS DEPOT 7 + MAINT DEPOT 7
B81 = B77 + B79

PROB DEPOT 8 = PROB 8*PART ON PLL*IN STK PLL*PROB 3
B83 = B231*B197*B209*B175

TRANS DEPOT 8 = PROB DEPOT 8*(AVERAGE TIME 2 + GO TO PLL STOCK + RTN TO ACFT + DEPOT TRANS TIME)
B85 = B83*(B235 + B207 + B205 + B9)

MAINT DEPOT 8 = PROB DEPOT 8*(MAINT ACTION + DEPOT MAINT)
B87 = B83*(B191 + B11)

TOTAL DEPOT 8 = TRANS DEPOT 8 + MAINT DEPOT 8
B89 = B85 + B87

PROB DEPOT 9 = (PROB DEPOT 8/PROB 3)*PROB 4
B91 = (B83/B175)*B177

TRANS DEPOT 9 = PROB DEPOT 9*(AVERAGE TIME 2 + GO TO PLL STOCK + RTN TO ACFT + DEPOT TRANS TIME)
B93 = B91*(B235 + B207 + B205 + B9)

MAINT DEPOT 9 = PROB DEPOT 9*(MAINT ACTION + DEPOT MAINT)
B95 = B91*(B191 + B11)

TOTAL DEPOT 9 = TRANS DEPOT 9 + MAINT DEPOT 9
B97 = B93 + B95

PROB DEPOT 10 = PROB 7*(1-CONTROL SUB)*PART IN THEATER*PROB 3
B99 = B183*(1-B211)*B221*B175

TRANS DEPOT 10 = PROB DEPOT 10*(AVERAGE TIME 1 + GO TO AMC + THEATER SEARCH + PART TO AMC + RTN TO ACFT + DEPOT TRANS TIME)
B101 = B99*(B229 + B199 + B219 + B223 + B205 + B9)

MAINT DEPOT 10 = PROB DEPOT 10*(MAINT ACTION + DEPOT MAINT)
B103 = B99*(B191 + B11)

TOTAL DEPOT 10 = TRANS DEPOT 10 + MAINT DEPOT 10
B105 = B101 + B103

PROB DEPOT 11 = (PROB DEPOT 10/PROB 3)*PROB 4
B107 = (B99/B175)*B177

TRANS DEPOT 11 = PROB DEPOT 11*(AVERAGE TIME 1 + GO TO AMC + THEATER SEARCH + PART TO AMC + RTN TO ACFT + DEPOT TRANS TIME)
B109 = B107*(B229 + B199 + B219 + B223 + B205 + B9)

MAINT DEPOT 11 = PROB DEPOT 11*(MAINT ACTION + DEPOT MAINT)
B111 = B107*(B191 + B11)

TOTAL DEPOT 11 = TRANS DEPOT 11 + MAINT DEPOT 11
B113 = B109 + B111

PROB DEPOT 12 = PROB 7*(1-CONTROL SUB)*(1-PART IN THEATER)*PROB 3
B115 = B183*(1-B211)*(1-B221)*B175

TRANS DEPOT 12 = PROB DEPOT 12*(AVERAGE TIME 1 + GO TO AMC + THEATER SEARCH + REQ FROM CONUS + RTN TO ACFT + DEPOT TRANS TIME)

B117 = B115*(B229 + B199 + B219 + B225 + B205 + B9)

MAINT DEPOT 12 = PROB DEPOT 12*(MAINT ACTION + DEPOT MAINT)
B119 = B115*(B191 + B11)

TOTAL DEPOT 12 = TRANS DEPOT 12 + MAINT DEPOT 12
B121 = B117 + B119

PROB DEPOT 13 = (PROB DEPOT 12/PROB 3)*PROB 4
B123 = (B115/B175)*B177

TRANS DEPOT 13 = PROB DEPOT 13*(AVERAGE TIME 1 + GO TO AMC + THEATER SEARCH + REQ FROM CONUS + RTN TO ACFT + DEPOT TRANS TIME)

B125 = B123*(B229 + B199 + B219 + B225 + B205 + B9)

MAINT DEPOT 13 = PROB DEPOT 13*(MAINT ACTION + DEPOT MAINT)
B127 = B123*(B191 + B11)

TOTAL DEPOT 13 = TRANS DEPOT 13 + MAINT DEPOT 13
B129 = B125 + B127

PROB DEPOT 14 = PROB 7*CONTROL SUB*PROB 3
B131 = B183*B211*B175

TRANS DEPOT 14 = PROB DEPOT 14*(AVERAGE TIME 1 + GO TO AMC + GO TO ACFT + REMOVE PART + RTN TO OWN ACFT + DEPOT TRANS TIME)
B133 = B131*(B229 + B199 + B213 + B215 + B217 + B9)

MAINT DEPOT 14 = PROB DEPOT 14*(MAINT ACTION + DEPOT MAINT)
B135 = B131*(B191 + B11)

TOTAL DEPOT 14 = TRANS DEPOT 14 + MAINT DEPOT 14
B137 = B133 + B135

PROB DEPOT 15 = PROB 7*CONTROL SUB*PROB 4
B139 = B183*B211*B177

TRANS DEPOT 15 = PROB DEPOT 15*(AVERAGE TIME 1 + GO TO AMC + GO TO ACFT + REMOVE PART + RTN TO OWN ACFT + DEPOT TRANS TIME)
B141 = B139*(B229 + B199 + B213 + B215 + B217 + B9)

MAINT DEPOT 15 = PROB DEPOT 15*(MAINT ACTION + DEPOT MAINT)
B143 = B139*(B191 + B11)

TOTAL DEPOT 15 = TRANS DEPOT 15 + MAINT DEPOT 15
B145 = B141 + B143

PROB FLT LN REPAIR = (PROB DEPOT 3/PROB 4)*((BIT APPLIES*INDICATES GO*HARDWARE OK) + (1-BIT APPLIES))
B147 = (B43/B177)*((B185*B7*B5) + (1-B185))

TIME FLT LN RPR = PROB FLT LN REP*MAINT ACTION
B149 = B147*B191

PROB PART FROM PLL = (PROB DEPOT 9/PROB 4)*((BIT APPLIES*INDICATES GO*HARDWARE OK) + (1-BIT APPLIES))
B151 = (B91/B177)*((B185*B7*B5) + (1-B185))

TIME PART FROM PLL = PROB PART FROM PLL*(AVERAGE TIME 2 + GO TO PLL STOCK + RTN TO ACFT + MAINT ACTION + RETURN FLT LN)
B153 = B151*(B235 + B207 + B205 + B191 + B195)

PROB PART FROM ASL = (PROB DEPOT 7/PROB 4)*((BIT APPLIES*INDICATES GO*HARDWARE OK) + (1-BIT APPLIES))
B155 = (B75/B177)*((B185*B7*B5) + (1-B185))

TIME PART FROM ASL = PROB PART FROM ASL*(AVERAGE TIME 1 + GO TO AMC + RTN TO ACFT + MAINT ACTION + RETURN FLT LN)
B157 = B155*(B229 + B199 + B205 + B191 + B195)

PROB PART FROM THEATER = (PROB DEPOT 11/PROB 4) *((BIT APPLIES*INDICATES GO*HARDWARE OK) + (1-BIT APPLIES))
B159 = (B107/B177)*((B185*B7*B5) + (1-B185))

TIME PART FROM THEATER = PROB PART THEAT*(AVERAGE TIME 1 + GO TO AMC + THEATER SEARCH + PART TO AMC + RTN TO ACFT + MAINT ACTION + RETURN FLT LN)
B161 = B159*(B229 + B199 + B219 + B223 + B205 + B191 + B195)

PROB PART FROM CONUS = (PROB DEPOT 13/PROB 4)*((BIT APPLIES*INDICATES GO*HARDWARE OK) + (1-BIT APPLIES))
B163 = (B123/B177)*((B185*B7*B5) + (1-B185))

TIME PART FROM CONUS = PROB PART CONUS*(AVERAGE TIME 1 + PART IN THEATER + REQ FROM CONUS + RTN TO ACFT + MAINT ACTION + RETURN FLT LN)
B165 = B163*(B229 + B221 + B225 + B205 + B191 + B195)

PROB CONTROL SUB = (PROB DEPOT 15/PROB 4)*((BIT APPLIES*INDICATES GO*HARDWARE OK) + (1-BIT APPLIES))
B167 = (B139/B177)*((B185*B7*B5) + (1-B185))

TIME CONTROL SUB = PROB CNTROL SUB*(AVERAGE TIME 1 + GO TO AMC + GO TO ACFT + REMOVE PART + RTN TO OWN ACFT + MAINT ACTION + RETURN FLT LN)
B169 = B167*(B229 + B199 + B213 + B215 + B217 + B191 + B195)

PROB 1 = BIT APPLIES*CAN ISOLATE + (1-BIT APPLIES)
B171 = B185*B3 + (1-B185)

PROB 2 = PROB 1*(1-FLT LN REPAIR)*(1-NEED PART)
B173 = B171*(1-B187)*(1-B189)

PROB 3 = BIT APPLIES*(1-INDICATES GO)
B175 = B185*(1-B7)

PROB 4 = BIT APPLIES*INDICATES GO*(1-HARDWARE OK)
B177 = B185*B7*(1-B5)

PROB 5 = BIT APPLIES*HARDWARE OK*INDICATES GO + (1-BIT APPLIES)
B179 = B185*B5*B7 + (1-B185)

PROB 6 = PROB 8*((PART ON PLL*(1-IN STK PLL)) + (1-PART ON PLL))
B181 = B231*((B197*(1-B209)) + (1-B197))

PROB 7 = PROB 6*((PART ON ASL*(1-IN STK ASL)) + (1-PART ON ASL))
B183 = B181*((B201*(1-B203)) + (1-B201))

AVERAGE TIME 1 = ((PROB 8*(1-PART ON PLL)*GO TO HSC) + (PROB 8*GO TO HSC*GO TO PLL STOCK*IN STK PLL))/PROB 6
B22 = ((B231*(1-B197)*B193) + (B231*B193*B207*B209))/B181

PROB 8 = PROB 1*NEED PART
B231 = B171*B189

PROB 9 = PROB 8*PART ON PLL*(1-IN STK PLL)
B233 = B231*B197*(1-B209)

AVERAGE TIME 2 = GO TO HSC
B235 = B193

PROB HSC W/O PART = PROB 2*((BIT APPLIES*INDICATES GO*HARDWARE OK) + (1-BIT APPLIES))
B237 = B173*((B185*B7*B5) + (1-B185))

TIME HSC W/O PART = PROB HSC W/O PART*(GO TO HSC + MAINT ACTION + RETURN FLT LN)
B239 = B237*(B193 + B191 + B195)

PROOF PROB = PROB OF DEPOT + PROB FLT LN REP + PROB PART FROM PLL + PROB PART FROM ASL + PROB PART THEAT + PROB PART CONUS + PROB CNTROL SUB + PROB HSC W/O PART)
B241 = (B13 + B147 + B151 + B155 + B159 + B163 + B167 + B237)

EAM Model Outputs

The following pages contain the outputs for the EAM model. Each table represents a sensitivity analysis for one of the three BIT failure modes and delay factors. The tables are set up with the events and data elements in the rows. Each column represents an excursion. The first two columns display the values for perfect BIT and for the AH-64 base case. The remainder of the columns display the values of BIT performance as the selected factor was varied. The excursions included are:

BIT Cannot Locate

Isolation Error

False Indication

Depot Maintenance Time

Depot Transit Time

Table 55

BIT Cannot Locate

EVENT/EXCURSION	PERFECT BIT	BASE	CANNOT LOC =5%	CANNOT LOC =4%	CANNOT LOC =3%	CANNOT LOC =2%	CANNOT LOC =1%	CANNOT LOC =0%
CAN ISOLATE	1.0000	0.9400	0.9500	0.9600	0.9700	0.9800	0.9900	1.0000
HARDWARE OK	1.0000	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
INDICATES GO	1.0000	0.9200	0.9200	0.9200	0.9200	0.9200	0.9200	0.9200
DEPOT TRANS TIME	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000
DEPOT MAINT	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500
PROBABILITY OF DEPOT	.0000	0.1699	0.1615	0.1532	0.1448	0.1364	0.1281	0.1197
TOTAL DEPOT TRANS	.0000	1.9191	1.8578	1.7966	1.7353	1.6740	1.6128	1.5515
TOTAL DEPOT MAINT	.0000	0.5916	0.5658	0.5400	0.5142	0.4885	0.4627	0.4369
TOTAL DEPOT TIME	.0000	2.5106	2.4236	2.3366	2.2495	2.1625	2.0755	1.9884
MTTR	0.5000	0.5795	0.5618	0.5459	0.5318	0.5194	0.5088	0.5000
AVERAGE DOWN TIME	5.5149	7.0886	7.0477	7.0068	6.9659	6.9250	6.8840	6.8431
AVAILABILITY	68.1682	59.0844	59.3206	59.5568	59.7929	60.0291	60.2652	60.5014
PROB DEPOT 1	.0000	0.0570	0.0475	0.0380	0.0285	0.0190	0.0095	0.0000
TRANS DEPOT 1	.0000	0.4560	0.3800	0.3040	0.2280	0.1520	0.0760	0.0000
MAINT DEPOT 1	.0000	0.1796	0.1496	0.1197	0.0898	0.0599	0.0299	0.0000
TOTAL DEPOT 1	.0000	0.6356	0.5296	0.4237	0.3178	0.2119	0.1059	0.0000
PROB DEPOT 2	.0000	0.0401	0.0405	0.0409	0.0413	0.0418	0.0422	0.0426
TRANS DEPOT 2	.0000	0.3211	0.3243	0.3275	0.3308	0.3340	0.3372	0.3405
MAINT DEPOT 2	.0000	0.1465	0.1480	0.1494	0.1509	0.1524	0.1539	0.1553
TOTAL DEPOT 2	.0000	0.4676	0.4723	0.4770	0.4817	0.4864	0.4911	0.4958
PROB DEPOT 3	.0000	0.0231	0.0233	0.0235	0.0238	0.0240	0.0242	0.0245
TRANS DEPOT 3	.0000	0.1846	0.1865	0.1883	0.1902	0.1921	0.1939	0.1958
MAINT DEPOT3	.0000	0.0842	0.0851	0.0859	0.0868	0.0876	0.0885	0.0893

Table 55 (Continued)

BIT Cannot Locate

EVENT/EXCURSION	PERFECT BIT	BASE	CANNOT LOC =5%	CANNOT LOC =4%	CANNOT LOC =3%	CANNOT LOC =2%	CANNOT LOC =1%	CANNOT LOC =0%
TOTAL DEPOT 3	.0000	0.2688	0.2716	0.2743	0.2770	0.2797	0.2824	0.2851
PROB DEPOT 4	.0000	0.0100	0.0101	0.0102	0.0103	0.0104	0.0105	0.0106
TRANS DEPOT 4	.0000	0.0853	0.0861	0.0870	0.0879	0.0887	0.0896	0.0904
MAINT DEPOT 4	.0000	0.0366	0.0370	0.0374	0.0377	0.0381	0.0385	0.0388
TOTAL DEPOT 4	.0000	0.1219	0.1231	0.1244	0.1256	0.1268	0.1280	0.1293
PROB DEPOT 5	.0000	0.0058	0.0058	0.0059	0.0059	0.0060	0.0061	0.0061
TRANS DEPOT 5	.0000	0.0490	0.0495	0.0500	0.0505	0.0510	0.0515	0.0520
MAINT DEPOT 5	.0000	0.0211	0.0213	0.0215	0.0217	0.0219	0.0221	0.0223
TOTAL DEPOT 5	.0000	0.0701	0.0708	0.0715	0.0722	0.0729	0.0736	0.0743
PROB DEPOT 6	.0000	0.0056	0.0056	0.0057	0.0057	0.0058	0.0058	0.0059
TRANS DEPOT 6	.0000	0.0534	0.0539	0.0545	0.0550	0.0555	0.0561	0.0566
MAINT DEPOT 6	.0000	0.0203	0.0205	0.0207	0.0209	0.0211	0.0213	0.0215
TOTAL DEPOT 6	.0000	0.0737	0.0744	0.0751	0.0759	0.0766	0.0774	0.0781
PROB DEPOT 7	.0000	0.0032	0.0032	0.0033	0.0033	0.0033	0.0034	0.0034
TRANS DEPOT 7	.0000	0.0307	0.0310	0.0313	0.0316	0.0319	0.0322	0.0326
MAINT DEPOT 7	.0000	0.0117	0.0118	0.0119	0.0120	0.0121	0.0122	0.0124
TOTAL DEPOT 7	.0000	0.0424	0.0428	0.0432	0.0436	0.0441	0.0445	0.0449
PROB DEPOT 8	.0000	0.0146	0.0148	0.0149	0.0151	0.0152	0.0154	0.0155
TRANS DEPOT 8	.0000	0.1360	0.1373	0.1387	0.1401	0.1414	0.1428	0.1442
MAINT DEPOT 8	.0000	0.0534	0.0539	0.0544	0.0550	0.0555	0.0561	0.0566
TOTAL DEPOT 8	.0000	0.1893	0.1912	0.1931	0.1951	0.1970	0.1989	0.2008
PROB DEPOT 9	.0000	0.0084	0.0085	0.0086	0.0087	0.0087	0.0088	0.0089
TRANS DEPOT 9	.0000	0.0782	0.0790	0.0798	0.0805	0.0813	0.0821	0.0829

Table 55 (Continued)

BIT Cannot Locate

EVENT/EXCURSION	PERFECT BIT	BASE	CANNOT LOC =5%	CANNOT LOC =4%	CANNOT LOC =3%	CANNOT LOC =2%	CANNOT LOC =1%	CANNOT LOC =0%
MAINT DEPOT 9	.0000	0.0307	0.0310	0.0313	0.0316	0.0319	0.0322	0.0325
TOTAL DEPOT 9	.0000	0.1089	0.1100	0.1111	0.1122	0.1133	0.1143	0.1154
PROB DEPOT 10	.0000	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
TRANS DEPOT 10	.0000	0.1236	0.1248	0.1261	0.1273	0.1286	0.1298	0.1311
MAINT DEPOT 10	.0000	0.0035	0.0035	0.0036	0.0036	0.0036	0.0037	0.0037
TOTAL DEPOT 10	.0000	0.1271	0.1284	0.1296	0.1309	0.1322	0.1335	0.1348
PROB DEPOT 11	.0000	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
TRANS DEPOT 11	.0000	0.0711	0.0718	0.0725	0.0732	0.0739	0.0746	0.0754
MAINT DEPOT 11	.0000	0.0020	0.0020	0.0020	0.0021	0.0021	0.0021	0.0021
TOTAL DEPOT 11	.0000	0.0731	0.0738	0.0745	0.0753	0.0760	0.0767	0.0775
PROB DEPOT 12	.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003
TRANS DEPOT 12	.0000	0.2083	0.2104	0.2125	0.2146	0.2167	0.2188	0.2209
MAINT DEPOT 12	.0000	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009
TOTAL DEPOT 12	.0000	0.2091	0.2112	0.2133	0.2155	0.2176	0.2197	0.2218
PROB DEPOT 13	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
TRANS DEPOT 13	.0000	0.1198	0.1210	0.1222	0.1234	0.1246	0.1258	0.1270
MAINT DEPOT 13	.0000	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
TOTAL DEPOT 13	.0000	0.1203	0.1215	0.1227	0.1239	0.1251	0.1263	0.1275
PROB DEPOT 14	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
TRANS DEPOT 14	.0000	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
MAINT DEPOT 14	.0000	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
TOTAL DEPOT 14	.0000	0.0018	0.0019	0.0019	0.0019	0.0019	0.0019	0.0020
PROB DEPOT 15	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Table 55 (Continued)

BIT Cannot Locate

EVENT/EXCURSION	PERFECT BIT	BASE	CANNOT LOC =5%	CANNOT LOC =4%	CANNOT LOC =3%	CANNOT LOC =2%	CANNOT LOC =1%	CANNOT LOC =0%
TRANS DEPOT 15	.0000	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
MAINT DEPOT 15	.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
TOTAL DEPOT 15	.0000	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011
PROB FLT LN REPAIR	0.5600	0.4649	0.4696	0.4742	0.4789	0.4836	0.4883	0.4930
TIME FLT LN RPR	0.2800	0.2324	0.2348	0.2371	0.2395	0.2418	0.2441	0.2465
PROB PART FROM PLL	0.2040	0.1693	0.1711	0.1728	0.1745	0.1762	0.1779	0.1796
TIME PART FROM PLL	0.4284	0.3556	0.3592	0.3628	0.3664	0.3700	0.3735	0.3771
PROB PART FROM ASL	0.0775	0.0644	0.0650	0.0656	0.0663	0.0669	0.0676	0.0682
TIME PART FROM ASL	0.1868	0.1550	0.1566	0.1582	0.1597	0.1613	0.1629	0.1644
PROB PART FROM THEAT	0.0133	0.0110	0.0112	0.0113	0.0114	0.0115	0.0116	0.0117
TIME PART FROM THEAT	1.6287	1.3520	1.3657	1.3793	1.3929	1.4065	1.4202	1.4338
PROB PART FROM CONUS	0.0033	0.0028	0.0028	0.0028	0.0028	0.0029	0.0029	0.0029
TIME PART FROM CONUS	2.8032	2.3270	2.3504	2.3739	2.3973	2.4208	2.4442	2.4676
PROB CONTROL SUB	0.0018	0.0015	0.0015	0.0016	0.0016	0.0016	0.0016	0.0016
TIME CONTROL SUB	0.0057	0.0048	0.0048	0.0049	0.0049	0.0050	0.0050	0.0051
PROB 1	1.0000	0.9430	0.9525	0.9620	0.9715	0.9810	0.9905	1.0000
PROB 2	0.1400	0.1320	0.1333	0.1347	0.1360	0.1373	0.1387	0.1400
PROB 3	.0000	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760
PROB 4	.0000	0.0437	0.0437	0.0437	0.0437	0.0437	0.0437	0.0437
PROB 5	1.0000	0.8803	0.8803	0.8803	0.8803	0.8803	0.8803	0.8803
PROB 6	0.0960	0.0905	0.0914	0.0924	0.0933	0.0942	0.0951	0.0960
PROB 7	0.0185	0.0174	0.0176	0.0178	0.0180	0.0181	0.0183	0.0185
BIT APPLIES	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500

Table 55 (Continued)

BIT Cannot Locate

EVENT/EXCURSION	PERFECT BIT	BASE	CANNOT LOC =5%	CANNOT LOC =4%	CANNOT LOC =3%	CANNOT LOC =2%	CANNOT LOC =1%	CANNOT LOC =0%
FLT LN REPAIR	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
NEED PART	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
MAINT ACTION	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
GO TO HSC	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
RETURN TO FLT LN	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
PART ON PLL	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500
GO TO AMC	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
PART ON ASL	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
IN STK ASL	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500
RTN TO ACFT	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
GO TO PLL STOCK	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
IN STK PLL	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
CONTROL SUB	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000
GO TO ACFT	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
REMOVE PART	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
RTN TO OWN ACFT	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000
THEATER SEARCH	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000
PART IN THEATER	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
PART TO AMC	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000
REQ FM CONUS	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000
BIT APPLIES	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
AVERAGE TIME 1	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094
PROBABILITY 8	0.3000	0.2829	0.2858	0.2886	0.2915	0.2943	0.2972	0.3000

Table 55 (Continued)

BIT Cannot Locate

EVENT/EXCURSION	PERFECT BIT	BASE	CANNOT LOC =5%	CANNOT LOC =4%	CANNOT LOC =3%	CANNOT LOC =2%	CANNOT LOC =1%	CANNOT LOC =0%
PROBABILITY 9	0.0510	0.0481	0.0486	0.0491	0.0495	0.0500	0.0505	0.0510
AVERAGE TIME 2	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
PROB HSC W/O PART	0.1400	0.1162	0.1174	0.1186	0.1197	0.1209	0.1221	0.1232
TIME HSC W/O PART	0.1820	0.1511	0.1526	0.1541	0.1556	0.1572	0.1587	0.1602
PROOF PROB	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
FLYING HOURS	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000
MTBEMA	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000
ELAPSED HOURS	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000
ACFT ASSIGNED	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000

Table 56

Isolation Error

EVENT/EXCURSION	PERFECT BIT	BASE	ISOLAT ERR =2.5%	ISOLAT ERR =2%	ISOLAT ERR =1.5%	ISOLAT ERR =1%	ISOLAT ERR =.5%	ISOLAT ERR =0%
CAN ISOLATE	1.0000	0.9400	0.9400	0.9400	0.9400	0.9400	0.9400	0.9400
HARDWARE OK	1.0000	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
INDICATES GO	1.0000	0.9200	0.9250	0.9300	0.9350	0.9400	0.9450	0.9500
DEPOT TRANS TIME	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000
DEPOT MAINT	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500
PROBABILITY OF DEPOT	.0000	0.1699	0.1656	0.1614	0.1571	0.1529	0.1486	0.1443
TOTAL DEPOT TRANS	.0000	1.9191	1.8639	1.8088	1.7536	1.6985	1.6433	1.5881
TOTAL DEPOT MAINT	.0000	0.5916	0.5760	0.5605	0.5450	0.5294	0.5139	0.4984
TOTAL DEPOT TIME	.0000	2.5106	2.4399	2.3693	2.2986	2.2279	2.1572	2.0865
MTTR	0.5000	0.5795	0.5768	0.5741	0.5714	0.5686	0.5659	0.5632
AVERAGE DOWN TIME	5.5149	7.0886	7.0414	6.9942	6.9470	6.8997	6.8525	6.8053
AVAILABILITY	68.1682	59.0844	59.3570	59.6295	59.9021	60.1747	60.4472	60.7198
PROB DEPOT 1	.0000	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570
TRANS DEPOT 1	.0000	0.4560	0.4560	0.4560	0.4560	0.4560	0.4560	0.4560
MAINT DEPOT 1	.0000	0.1796	0.1796	0.1796	0.1796	0.1796	0.1796	0.1796
TOTAL DEPOT 1	.0000	0.6356	0.6356	0.6356	0.6356	0.6356	0.6356	0.6356
PROB DEPOT 2	.0000	0.0401	0.0376	0.0351	0.0326	0.0301	0.0276	0.0251
TRANS DEPOT 2	.0000	0.3211	0.3010	0.2809	0.2609	0.2408	0.2207	0.2007
MAINT DEPOT 2	.0000	0.1465	0.1373	0.1282	0.1190	0.1099	0.1007	0.0916
TOTAL DEPOT 2	.0000	0.4676	0.4383	0.4091	0.3799	0.3507	0.3214	0.2922
PROB DEPOT 3	.0000	0.0231	0.0232	0.0233	0.0235	0.0236	0.0237	0.0238
TRANS DEPOT 3	.0000	0.1846	0.1856	0.1866	0.1876	0.1886	0.1896	0.1906
MAINT DEPOT3	.0000	0.0842	0.0847	0.0851	0.0856	0.0861	0.0865	0.0870

Table 56 (Continued)

Isolation Error

EVENT/EXCURSION	PERFECT BIT	BASE	ISOLAT ERR =2.5%	ISOLAT ERR =2%	ISOLAT ERR =1.5%	ISOLAT ERR =1%	ISOLAT ERR =.5%	ISOLAT ERR =0%
TOTAL DEPOT 3	.0000	0.2688	0.2703	0.2718	0.2732	0.2747	0.2762	0.2776
PROB DEPOT 4	.0000	0.0100	0.0094	0.0088	0.0082	0.0075	0.0069	0.0063
TRANS DEPOT 4	.0000	0.0853	0.0800	0.0746	0.0693	0.0640	0.0586	0.0533
MAINT DEPOT 4	.0000	0.0366	0.0343	0.0320	0.0298	0.0275	0.0252	0.0229
TOTAL DEPOT 4	.0000	0.1219	0.1143	0.1067	0.0990	0.0914	0.0838	0.0762
PROB DEPOT 5	.0000	0.0058	0.0058	0.0058	0.0059	0.0059	0.0059	0.0060
TRANS DEPOT 5	.0000	0.0490	0.0493	0.0496	0.0498	0.0501	0.0504	0.0506
MAINT DEPOT 5	.0000	0.0211	0.0212	0.0213	0.0214	0.0215	0.0216	0.0217
TOTAL DEPOT 5	.0000	0.0701	0.0705	0.0709	0.0712	0.0716	0.0720	0.0724
PROB DEPOT 6	.0000	0.0056	0.0052	0.0049	0.0045	0.0042	0.0038	0.0035
TRANS DEPOT 6	.0000	0.0534	0.0501	0.0467	0.0434	0.0400	0.0367	0.0334
MAINT DEPOT 6	.0000	0.0203	0.0190	0.0177	0.0165	0.0152	0.0139	0.0127
TOTAL DEPOT 6	.0000	0.0737	0.0691	0.0645	0.0599	0.0552	0.0506	0.0460
PROB DEPOT 7	.0000	0.0032	0.0032	0.0032	0.0032	0.0033	0.0033	0.0033
TRANS DEPOT 7	.0000	0.0307	0.0309	0.0310	0.0312	0.0314	0.0315	0.0317
MAINT DEPOT 7	.0000	0.0117	0.0117	0.0118	0.0119	0.0119	0.0120	0.0120
TOTAL DEPOT 7	.0000	0.0424	0.0426	0.0428	0.0430	0.0433	0.0435	0.0437
PROB DEPOT 8	.0000	0.0146	0.0137	0.0128	0.0119	0.0110	0.0101	0.0091
TRANS DEPOT 8	.0000	0.1360	0.1275	0.1190	0.1105	0.1020	0.0935	0.0850
MAINT DEPOT8	.0000	0.0534	0.0500	0.0467	0.0434	0.0400	0.0367	0.0334
TOTAL DEPOT 8	.0000	0.1893	0.1775	0.1657	0.1538	0.1420	0.1302	0.1183
PROB DEPOT 9	.0000	0.0084	0.0085	0.0085	0.0085	0.0086	0.0086	0.0087
TRANS DEPOT 9	.0000	0.0782	0.0786	0.0790	0.0795	0.0799	0.0803	0.0807

Table 56 (Continued)

Isolation Error

EVENT/EXCURSION	PERFECT BIT	BASE	ISOLAT ERR =2.5%	ISOLAT ERR =2%	ISOLAT ERR =1.5%	ISOLAT ERR =1%	ISOLAT ERR =.5%	ISOLAT ERR =0%
MAINT DEPOT 9	.0000	0.0307	0.0309	0.0310	0.0312	0.0314	0.0315	0.0317
TOTAL DEPOT 9	.0000	0.1089	0.1095	0.1100	0.1106	0.1112	0.1118	0.1124
PROB DEPOT 10	.0000	0.0010	0.0009	0.0008	0.0008	0.0007	0.0007	0.0006
TRANS DEPOT 10	.0000	0.1236	0.1159	0.1081	0.1004	0.0927	0.0850	0.0772
MAINT DEPOT 10	.0000	0.0035	0.0033	0.0030	0.0028	0.0026	0.0024	0.0022
TOTAL DEPOT 10	.0000	0.1271	0.1191	0.1112	0.1032	0.0953	0.0874	0.0794
PROB DEPOT 11	.0000	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
TRANS DEPOT 11	.0000	0.0711	0.0715	0.0718	0.0722	0.0726	0.0730	0.0734
MAINT DEPOT 11	.0000	0.0020	0.0020	0.0020	0.0020	0.0020	0.0021	0.0021
TOTAL DEPOT 11	.0000	0.0731	0.0735	0.0739	0.0743	0.0747	0.0751	0.0755
PROB DEPOT 12	.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001
TRANS DEPOT 12	.0000	0.2083	0.1952	0.1822	0.1692	0.1562	0.1432	0.1302
MAINT DEPOT 12	.0000	0.0009	0.0008	0.0008	0.0007	0.0007	0.0006	0.0005
TOTAL DEPOT 12	.0000	0.2091	0.1961	0.1830	0.1699	0.1569	0.1438	0.1307
PROB DEPOT 13	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
TRANS DEPOT 13	.0000	0.1198	0.1204	0.1211	0.1217	0.1224	0.1230	0.1237
MAINT DEPOT 13	.0000	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
TOTAL DEPOT 13	.0000	0.1203	0.1209	0.1216	0.1222	0.1229	0.1235	0.1242
PROB DEPOT 14	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
TRANS DEPOT 14	.0000	0.0014	0.0013	0.0012	0.0011	0.0010	0.0009	0.0009
MAINT DEPOT 14	.0000	0.0005	0.0005	0.0004	0.0004	0.0004	0.0003	0.0003
TOTAL DEPOT 14	.0000	0.0018	0.0017	0.0016	0.0015	0.0014	0.0013	0.0012
PROB DEPOT 15	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Table 56 (Continued)

Isolation Error

EVENT/EXCURSION	PERFECT BIT	BASE	ISOLAT ERR =2.5%	ISOLAT ERR =2%	ISOLAT ERR =1.5%	ISOLAT ERR =1%	ISOLAT ERR =.5%	ISOLAT ERR =0%
TRANS DEPOT 15	.0000	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
MAINT DEPOT 15	.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
TOTAL DEPOT 15	.0000	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011
PROB FLT LN REPAIR	0.5600	0.4649	0.4673	0.4696	0.4720	0.4744	0.4768	0.4792
TIME FLT LN RPR	0.2800	0.2324	0.2336	0.2348	0.2360	0.2372	0.2384	0.2396
PROB PART FROM PLL	0.2040	0.1693	0.1702	0.1711	0.1719	0.1728	0.1737	0.1746
TIME PART FROM PLL	0.4284	0.3556	0.3574	0.3593	0.3611	0.3629	0.3647	0.3666
PROB PART FROM ASL	0.0775	0.0644	0.0647	0.0650	0.0653	0.0657	0.0660	0.0663
TIME PART FROM ASL	0.1868	0.1550	0.1558	0.1566	0.1574	0.1582	0.1590	0.1598
PROB PART FROM THEAT	0.0133	0.0110	0.0111	0.0112	0.0112	0.0113	0.0113	0.0114
TIME PART FROM THEAT	1.6287	1.3520	1.3590	1.3659	1.3728	1.3798	1.3867	1.3936
PROB PART FROM CONUS	0.0033	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028
TIME PART FROM CONUS	2.8032	2.3270	2.3389	2.3508	2.3628	2.3747	2.3866	2.3986
PROB CONTROL SUB	0.0018	0.0015	0.0015	0.0015	0.0016	0.0016	0.0016	0.0016
TIME CONTROL SUB	0.0057	0.0048	0.0048	0.0048	0.0048	0.0049	0.0049	0.0049
PROB 1	1.0000	0.9430	0.9430	0.9430	0.9430	0.9430	0.9430	0.9430
PROB 2	0.1400	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
PROB 3	.0000	0.0760	0.0712	0.0665	0.0617	0.0570	0.0523	0.0475
PROB 4	.0000	0.0437	0.0439	0.0442	0.0444	0.0447	0.0449	0.0451
PROB 5	1.0000	0.8803	0.8848	0.8893	0.8938	0.8984	0.9029	0.9074
PROB 6	0.0960	0.0905	0.0905	0.0905	0.0905	0.0905	0.0905	0.0905
PROB 7	0.0185	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174
BIT APPLIES	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500

Table 56 (Continued)

Isolation Error

EVENT/EXCURSION	PERFECT BIT	BASE	ISOLAT ERR =2.5%	ISOLAT ERR =2%	ISOLAT ERR =1.5%	ISOLAT ERR =1%	ISOLAT ERR =.5%	ISOLAT ERR =0%
FLT LN REPAIR	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
NEED PART	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
MAINT ACTION	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
GO TO MSC	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
RETURN TO FLT LN	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
PART ON PLL	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500
GO TO AMC	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
PART ON ASL	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
IN STK ASL	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500
RTN TO ACFT	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
GO TO PLL STOCK	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
IN STK PLL	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
CONTROL SUB	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000
GO TO ACFT	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
REMOVE PART	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
RTN TO OWN ACFT	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000
THEATER SEARCH	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000
PART IN THEATER	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
PART TO AMC	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000
REQ FM CONUS	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000
BIT APPLIES	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
AVERAGE TIME 1	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094
PROBABILITY 8	0.3000	0.2829	0.2829	0.2829	0.2829	0.2829	0.2829	0.2829

Table 56 (Continued)

Isolation Error

EVENT/EXCURSION	PERFECT BIT	BASE	ISOLAT ERR =2.5%	ISOLAT ERR =2%	ISOLAT ERR =1.5%	ISOLAT ERR =1%	ISOLAT ERR =.5%	ISOLAT ERR =0%
PROBABILITY 9	0.0510	0.0481	0.0481	0.0481	0.0481	0.0481	0.0481	0.0481
AVERAGE TIME 2	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
PROB HSC W/O PART	0.1400	0.1162	0.1168	0.1174	0.1180	0.1186	0.1192	0.1198
TIME HSC W/O PART	0.1820	0.1511	0.1519	0.1526	0.1534	0.1542	0.1550	0.1557
PROOF PROB	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
FLYING HOURS	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000
MTBEMA	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000
ELAPSED HOURS	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000
ACFT ASSIGNED	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000

Table 57

False Indication

EVENT/EXCURSION	PERFECT BIT	BASE	FALSE IND =4%	FALSE IND =3%	FALSE IND =2%	FALSE IND =1%	FALSE IND =0%
CAN ISOLATE	1.0000	0.9400	0.9400	0.9400	0.9400	0.9400	0.9400
HARDWARE OK	1.0000	0.9500	0.9600	0.9700	0.9800	0.9900	1.0000
INDICATES GO	1.0000	0.9200	0.9300	0.9400	0.9500	0.9600	0.9700
DEPOT TRANS TIME	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000
DEPOT MAINT	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500
PROBABILITY OF DEPOT	.0000	0.1699	0.1530	0.1360	0.1188	0.1014	0.0839
TOTAL DEPOT TRANS	.0000	1.9191	1.7008	1.4802	1.2572	1.0319	0.8044
TOTAL DEPOT MAINT	.0000	0.5916	0.5301	0.4680	0.4052	0.3417	0.2776
TOTAL DEPOT TIME	.0000	2.5106	2.2309	1.9481	1.6624	1.3737	1.0820
MTTR	0.5000	0.5795	0.5688	0.5579	0.5470	0.5360	0.5248
AVERAGE DOWN TIME	5.5149	7.0886	6.9017	6.7128	6.5220	6.3291	6.1343
AVAILABILITY	68.1682	59.0844	60.1632	61.2534	62.3551	63.4683	64.5929
PROB DEPOT 1	.0000	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570
TRANS DEPOT 1	.0000	0.4560	0.4560	0.4560	0.4560	0.4560	0.4560
MAINT DEPOT 1	.0000	0.1796	0.1796	0.1796	0.1796	0.1796	0.1796
TOTAL DEPOT 1	.0000	0.6356	0.6356	0.6356	0.6356	0.6356	0.6356
PROB DEPOT 2	.0000	0.0401	0.0351	0.0301	0.0251	0.0201	0.0151
TRANS DEPOT 2	.0000	0.3211	0.2809	0.2408	0.2007	0.1605	0.1204
MAINT DEPOT 2	.0000	0.1465	0.1282	0.1099	0.0916	0.0732	0.0549
TOTAL DEPOT 2	.0000	0.4676	0.4091	0.3507	0.2922	0.2338	0.1753
PROB DEPOT 3	.0000	0.0231	0.0187	0.0141	0.0095	0.0048	.0000
TRANS DEPOT 3	.0000	0.1846	0.1493	0.1132	0.0763	0.0385	.0000
MAINT DEPOT3	.0000	0.0842	0.0681	0.0516	0.0348	0.0176	.0000

Table 57 (Continued)

False Indication

EVENT/EXCURSION	PERFECT BIT	BASE	FALSE IND =4%	FALSE IND =3%	FALSE IND =2%	FALSE IND =1%	FALSE IND =0%
TOTAL DEPOT 3	.0000	0.2688	0.2174	0.1648	0.1110	0.0561	.0000
PROB DEPOT 4	.0000	0.0100	0.0088	0.0075	0.0063	0.0050	0.0038
TRANS DEPOT 4	.0000	0.0853	0.0746	0.0640	0.0533	0.0426	0.0320
MAINT DEPOT 4	.0000	0.0366	0.0320	0.0275	0.0229	0.0183	0.0137
TOTAL DEPOT 4	.0000	0.1219	0.1067	0.0914	0.0762	0.0610	0.0457
PROB DEPOT 5	.0000	0.0058	0.0047	0.0035	0.0024	0.0012	.0000
TRANS DEPOT 5	.0000	0.0490	0.0397	0.0301	0.0203	0.0102	.0000
MAINT DEPOT 5	.0000	0.0211	0.0170	0.0129	0.0087	0.0044	.0000
TOTAL DEPOT 5	.0000	0.0701	0.0567	0.0430	0.0290	0.0146	.0000
PROB DEPOT 6	.0000	0.0056	0.0049	0.0042	0.0035	0.0028	0.0021
TRANS DEPOT 6	.0000	0.0534	0.0467	0.0400	0.0334	0.0267	0.0200
MAINT DEPOT 6	.0000	0.0203	0.0177	0.0152	0.0127	0.0101	0.0076
TOTAL DEPOT 6	.0000	0.0737	0.0645	0.0552	0.0460	0.0368	0.0276
PROB DEPOT 7	.0000	0.0032	0.0026	0.0020	0.0013	0.0007	.0000
TRANS DEPOT 7	.0000	0.0307	0.0248	0.0188	0.0127	0.0064	.0000
MAINT DEPOT 7	.0000	0.0117	0.0094	0.0071	0.0048	0.0024	.0000
TOTAL DEPOT 7	.0000	0.0424	0.0343	0.0260	0.0175	0.0088	.0000
PROB DEPOT 8	.0000	0.0146	0.0128	0.0110	0.0091	0.0073	0.0055
TRANS DEPOT 8	.0000	0.1360	0.1190	0.1020	0.0850	0.0680	0.0510
MAINT DEPOT8	.0000	0.0534	0.0467	0.0400	0.0334	0.0267	0.0200
TOTAL DEPOT 8	.0000	0.1893	0.1657	0.1420	0.1183	0.0947	0.0710
PROB DEPOT 9	.0000	0.0084	0.0068	0.0052	0.0035	0.0018	.0000
TRANS DEPOT 9	.0000	0.0782	0.0632	0.0479	0.0323	0.0163	.0000

Table 57 (Continued)

False Indication

EVENT/EXCURSION	PERFECT BIT	BASE	FALSE IND =4%	FALSE IND =3%	FALSE IND =2%	FALSE IND =1%	FALSE IND =0%
MAINT DEPOT 9	.0000	0.0307	0.0248	0.0188	0.0127	0.0064	.0000
TOTAL DEPOT 9	.0000	0.1089	0.0880	0.0667	0.0450	0.0227	.0000
PROB DEPOT 10	.0000	0.0010	0.0008	0.0007	0.0006	0.0005	0.0004
TRANS DEPOT 10	.0000	0.1236	0.1081	0.0927	0.0772	0.0618	0.0463
MAINT DEPOT 10	.0000	0.0035	0.0030	0.0026	0.0022	0.0017	0.0013
TOTAL DEPOT 10	.0000	0.1271	0.1112	0.0953	0.0794	0.0635	0.0477
PROB DEPOT 11	.0000	0.0005	0.0004	0.0003	0.0002	0.0001	.0000
TRANS DEPOT 11	.0000	0.0711	0.0575	0.0436	0.0294	0.0148	.0000
MAINT DEPOT 11	.0000	0.0020	0.0016	0.0012	0.0008	0.0004	.0000
TOTAL DEPOT 11	.0000	0.0731	0.0591	0.0448	0.0302	0.0152	.0000
PROB DEPOT 12	.0000	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001
TRANS DEPOT 12	.0000	0.2083	0.1822	0.1562	0.1302	0.1041	0.0781
MAINT DEPOT 12	.0000	0.0009	0.0008	0.0007	0.0005	0.0004	0.0003
TOTAL DEPOT 12	.0000	0.2091	0.1830	0.1569	0.1307	0.1046	0.0784
PROB DEPOT 13	.0000	0.0001	0.0001	0.0001	0.0001	.0000	.0000
TRANS DEPOT 13	.0000	0.1198	0.0968	0.0734	0.0495	0.0250	.0000
MAINT DEPOT 13	.0000	0.0005	0.0004	0.0003	0.0002	0.0001	.0000
TOTAL DEPOT 13	.0000	0.1203	0.0972	0.0737	0.0497	0.0251	.0000
PROB DEPOT 14	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	.0000
TRANS DEPOT 14	.0000	0.0014	0.0012	0.0010	0.0009	0.0007	0.0005
MAINT DEPOT 14	.0000	0.0005	0.0004	0.0004	0.0003	0.0002	0.0002
TOTAL DEPOT 14	.0000	0.0018	0.0016	0.0014	0.0012	0.0009	0.0007
PROB DEPOT 15	.0000	0.0001	0.0001	.0000	.0000	.0000	.0000

Table 57 (Continued)

False Indication

EVENT/EXCURSION	PERFECT BIT	BASE	FALSE IND =4%	FALSE IND =3%	FALSE IND =2%	FALSE IND =1%	FALSE IND =0%
TRANS DEPOT 15	.0000	0.0008	0.0006	0.0005	0.0003	0.0002	.0000
MAINT DEPOT 15	.0000	0.0003	0.0002	0.0002	0.0001	0.0001	.0000
TOTAL DEPOT 15	.0000	0.0011	0.0009	0.0007	0.0004	0.0002	.0000
PROB FLT LN REPAIR	0.5600	0.4649	0.4743	0.4838	0.4935	0.5032	0.5130
TIME FLT LN RPR	0.2800	0.2324	0.2372	0.2419	0.2467	0.2516	0.2565
PROB PART FROM PLL	0.2040	0.1693	0.1728	0.1763	0.1798	0.1833	0.1869
TIME PART FROM PLL	0.4284	0.3556	0.3628	0.3701	0.3775	0.3849	0.3925
PROB PART FROM ASL	0.0775	0.0644	0.0657	0.0670	0.0683	0.0697	0.0710
TIME PART FROM ASL	0.1868	0.1550	0.1582	0.1614	0.1646	0.1678	0.1711
PROB PART FROM THEAT	0.0133	0.0110	0.0113	0.0115	0.0117	0.0120	0.0122
TIME PART FROM THEAT	1.6287	1.3520	1.3795	1.4072	1.4352	1.4635	1.4921
PROB PART FROM CONUS	0.0033	0.0028	0.0028	0.0029	0.0029	0.0030	0.0030
TIME PART FROM CONUS	2.8032	2.3270	2.3742	2.4219	2.4701	2.5188	2.5681
PROB CONTROL SUB	0.0018	0.0015	0.0016	0.0016	0.0016	0.0017	0.0017
TIME CONTROL SUB	0.0057	0.0048	0.0049	0.0050	0.0051	0.0052	0.0053
PROB 1	1.0000	0.9430	0.9430	0.9430	0.9430	0.9430	0.9430
PROB 2	0.1400	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
PROB 3	.0000	0.0760	0.0665	0.0570	0.0475	0.0380	0.0285
PROB 4	.0000	0.0437	0.0353	0.0268	0.0181	0.0091	.0000
PROB 5	1.0000	0.8803	0.8982	0.9162	0.9345	0.9529	0.9715
PROB 6	0.0960	0.0905	0.0905	0.0905	0.0905	0.0905	0.0905
PROB 7	0.0185	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174
BIT APPLIES	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500

Table 57 (Continued)

False Indication

EVENT/EXCURSION	PERFECT BIT	BASE	FALSE IND =4%	FALSE IND =3%	FALSE IND =2%	FALSE IND =1%	FALSE IND =0%
FLT LN REPAIR	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
NEED PART	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
MAINT ACTION	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
GO TO HSC	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
RETURN TO FLT LN	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
PART ON PLL	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500
GO TO AMC	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
PART ON ASL	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
IN STK ASL	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500
RTN TO ACFT	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
GO TO PLL STOCK	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
IN STK PLL	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
CONTROL SUB	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000
GO TO ACFT	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
REMOVE PART	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
RTN TO OWN ACFT	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000
THEATER SEARCH	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000
PART IN THEATER	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
PART TO AMC	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000
REQ FM CONUS	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000
BIT APPLIES	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
AVERAGE TIME 1	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094
PROBABILITY 8	0.3000	0.2829	0.2829	0.2829	0.2829	0.2829	0.2829

Table 57 (Continued)

False Indication

EVENT/EXCURSION	PERFECT BIT	BASE	FALSE IND =4%	FALSE IND =3%	FALSE IND =2%	FALSE IND =1%	FALSE IND =0%
PROBABILITY 9	0.0510	0.0481	0.0481	0.0481	0.0481	0.0481	0.0481
AVERAGE TIME 2	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
PROB MSC W/O PART	0.1400	0.1162	0.1186	0.1210	0.1234	0.1258	0.1283
TIME MSC W/O PART	0.1820	0.1511	0.1541	0.1572	0.1604	0.1635	0.1667
PROOF PROB	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
FLYING HOURS	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000
MTBEMA	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000
ELAPSED HOURS	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000
ACFT ASSIGNED	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000

Table 58

Depot Maintenance Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT MAINT=3	DEPOT MAINT=2.5	DEPOT MAINT=2	DEPOT MAINT=1.5	DEPOT MAINT=1	DEPOT MAINT=.5
CAN ISOLATE	1.0000	0.9400	0.9400	0.9400	0.9400	0.9400	0.9400	0.9400
HARDWARE OK	1.0000	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
INDICATES GO	1.0000	0.9200	0.9200	0.9200	0.9200	0.9200	0.9200	0.9200
DEPOT TRANS TIME	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000
DEPOT MAINT	3.1500	3.1500	3.0000	2.5000	2.0000	1.5000	1.0000	0.5000
PROB OF DEPOT	.0000	0.1699	0.1699	0.1699	0.1699	0.1699	0.1699	0.1699
TOTAL DEPOT TRAN	.0000	1.9191	1.9191	1.9191	1.9191	1.9191	1.9191	1.9191
TOTAL DEPOT MAIN	.0000	0.5916	0.5661	0.4811	0.3962	0.3113	0.2263	0.1414
TOTAL DEPOT TIME	.0000	2.5106	2.4851	2.4002	2.3153	2.2303	2.1454	2.0605
MTTR	0.5000	0.5795	0.5780	0.5732	0.5683	0.5635	0.5586	0.5538
AVERAGE DOWN TIM	5.5149	7.0886	7.0631	6.9782	6.8933	6.8083	6.7234	6.6384
AVAILABILITY	68.1682	59.0844	59.2315	59.7218	60.2120	60.7023	61.1926	61.6828
PROB DEPOT 1	.0000	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570
TRANS DEPOT 1	.0000	0.4560	0.4560	0.4560	0.4560	0.4560	0.4560	0.4560
MAINT DEPOT 1	.0000	0.1796	0.1710	0.1425	0.1140	0.0855	0.0570	0.0285
TOTAL DEPOT 1	.0000	0.6356	0.6270	0.5985	0.5700	0.5415	0.5130	0.4845
PROB DEPOT 2	.0000	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401
TRANS DEPOT 2	.0000	0.3211	0.3211	0.3211	0.3211	0.3211	0.3211	0.3211
MAINT DEPOT 2	.0000	0.1465	0.1405	0.1204	0.1003	0.0803	0.0602	0.0401
TOTAL DEPOT 2	.0000	0.4676	0.4615	0.4415	0.4214	0.4013	0.3813	0.3612
PROB DEPOT 3	.0000	0.0231	0.0231	0.0231	0.0231	0.0231	0.0231	0.0231
TRANS DEPOT 3	.0000	0.1846	0.1846	0.1846	0.1846	0.1846	0.1846	0.1846
MAINT DEPOT3	.0000	0.0842	0.0808	0.0692	0.0577	0.0462	0.0346	0.0231

Table 58 (Continued)

Depot Maintenance Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT MAINT=3	DEPOT MAINT=2.5	DEPOT MAINT=2	DEPOT MAINT=1.5	DEPOT MAINT=1	DEPOT MAINT=.5
TOTAL DEPOT 3	.0000	0.2688	0.2654	0.2538	0.2423	0.2308	0.2192	0.2077
PROB DEPOT 4	.0000	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100
TRANS DEPOT 4	.0000	0.0853	0.0853	0.0853	0.0853	0.0853	0.0853	0.0853
MAINT DEPOT 4	.0000	0.0366	0.0351	0.0301	0.0251	0.0201	0.0151	0.0100
TOTAL DEPOT 4	.0000	0.1219	0.1204	0.1154	0.1104	0.1054	0.1003	0.0953
PROB DEPOT 5	.0000	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058
TRANS DEPOT 5	.0000	0.0490	0.0490	0.0490	0.0490	0.0490	0.0490	0.0490
MAINT DEPOT 5	.0000	0.0211	0.0202	0.0173	0.0144	0.0115	0.0087	0.0058
TOTAL DEPOT 5	.0000	0.0701	0.0692	0.0663	0.0635	0.0606	0.0577	0.0548
PROB DEPOT 6	.0000	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056
TRANS DEPOT 6	.0000	0.0534	0.0534	0.0534	0.0534	0.0534	0.0534	0.0534
MAINT DEPOT 6	.0000	0.0203	0.0194	0.0167	0.0139	0.0111	0.0083	0.0056
TOTAL DEPOT 6	.0000	0.0737	0.0728	0.0701	0.0673	0.0645	0.0617	0.0589
PROB DEPOT 7	.0000	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032
TRANS DEPOT 7	.0000	0.0307	0.0307	0.0307	0.0307	0.0307	0.0307	0.0307
MAINT DEPOT 7	.0000	0.0117	0.0112	0.0096	0.0080	0.0064	0.0048	0.0032
TOTAL DEPOT 7	.0000	0.0424	0.0419	0.0403	0.0387	0.0371	0.0355	0.0339
PROB DEPOT 8	.0000	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146
TRANS DEPOT 8	.0000	0.1360	0.1360	0.1360	0.1360	0.1360	0.1360	0.1360
MAINT DEPOT8	.0000	0.0534	0.0512	0.0439	0.0366	0.0292	0.0219	0.0146
TOTAL DEPOT 8	.0000	0.1893	0.1871	0.1798	0.1725	0.1652	0.1579	0.1506
PROB DEPOT 9	.0000	0.0084	0.0084	0.0084	0.0084	0.0084	0.0084	0.0084
TRANS DEPOT 9	.0000	0.0782	0.0782	0.0782	0.0782	0.0782	0.0782	0.0782

Table 58 (Continued)

Depot Maintenance Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT MAINT=3	DEPOT MAINT=2.5	DEPOT MAINT=2	DEPOT MAINT=1.5	DEPOT MAINT=1	DEPOT MAINT=.5
MAINT DEPOT 9	.0000	0.0307	0.0294	0.0252	0.0210	0.0168	0.0126	0.0084
TOTAL DEPOT 9	.0000	0.1089	0.1076	0.1034	0.0992	0.0950	0.0908	0.0866
PROB DEPOT 10	.0000	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
TRANS DEPOT 10	.0000	0.1236	0.1236	0.1236	0.1236	0.1236	0.1236	0.1236
MAINT DEPOT 10	.0000	0.0035	0.0033	0.0029	0.0024	0.0019	0.0014	0.0010
TOTAL DEPOT 10	.0000	0.1271	0.1269	0.1265	0.1260	0.1255	0.1250	0.1245
PROB DEPOT 11	.0000	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
TRANS DEPOT 11	.0000	0.0711	0.0711	0.0711	0.0711	0.0711	0.0711	0.0711
MAINT DEPOT 11	.0000	0.0020	0.0019	0.0016	0.0014	0.0011	0.0008	0.0005
TOTAL DEPOT 11	.0000	0.0731	0.0730	0.0727	0.0724	0.0722	0.0719	0.0716
PROB DEPOT 12	.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
TRANS DEPOT 12	.0000	0.2083	0.2083	0.2083	0.2083	0.2083	0.2083	0.2083
MAINT DEPOT 12	.0000	0.0009	0.0008	0.0007	0.0006	0.0005	0.0004	0.0002
TOTAL DEPOT 12	.0000	0.2091	0.2091	0.2090	0.2089	0.2087	0.2086	0.2085
PROB DEPOT 13	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
TRANS DEPOT 13	.0000	0.1198	0.1198	0.1198	0.1198	0.1198	0.1198	0.1198
MAINT DEPOT 13	.0000	0.0005	0.0005	0.0004	0.0003	0.0003	0.0002	0.0001
TOTAL DEPOT 13	.0000	0.1203	0.1202	0.1202	0.1201	0.1200	0.1200	0.1199
PROB DEPOT 14	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
TRANS DEPOT 14	.0000	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
MAINT DEPOT 14	.0000	0.0005	0.0005	0.0004	0.0003	0.0003	0.0002	0.0001
TOTAL DEPOT 14	.0000	0.0018	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015
PROB DEPOT 15	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Table 58 (Continued)

Depot Maintenance Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT MAINT=3	DEPOT MAINT=2.5	DEPOT MAINT=2	DEPOT MAINT=1.5	DEPOT MAINT=1	DEPOT MAINT=.5
TRANS DEPOT 15	.0000	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
MAINT DEPOT 15	.0000	0.0003	0.0003	0.0002	0.0002	0.0002	0.0001	0.0001
TOTAL DEPOT 15	.0000	0.0011	0.0011	0.0010	0.0010	0.0009	0.0009	0.0009
PROB FLT LN REPA	0.5600	0.4649	0.4649	0.4649	0.4649	0.4649	0.4649	0.4649
TIME FLT LN RPR	0.2800	0.2324	0.2324	0.2324	0.2324	0.2324	0.2324	0.2324
PROB PART FROM P	0.2040	0.1693	0.1693	0.1693	0.1693	0.1693	0.1693	0.1693
TIME PART FROM P	0.4284	0.3556	0.3556	0.3556	0.3556	0.3556	0.3556	0.3556
PROB PART FROM A	0.0775	0.0644	0.0644	0.0644	0.0644	0.0644	0.0644	0.0644
TIME PART FROM A	0.1868	0.1550	0.1550	0.1550	0.1550	0.1550	0.1550	0.1550
PROB PART FROM T	0.0133	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110
TIME PART FROM T	1.6287	1.3520	1.3520	1.3520	1.3520	1.3520	1.3520	1.3520
PROB PART FROM C	0.0033	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028
TIME PART FROM C	2.8032	2.3270	2.3270	2.3270	2.3270	2.3270	2.3270	2.3270
PROB CONTROL SUB	0.0018	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
TIME CONTROL SUB	0.0057	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
PROB 1	1.0000	0.9430	0.9430	0.9430	0.9430	0.9430	0.9430	0.9430
PROB 2	0.1400	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
PROB 3	.0000	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760
PROB 4	.0000	0.0437	0.0437	0.0437	0.0437	0.0437	0.0437	0.0437
PROB 5	1.0000	0.8803	0.8803	0.8803	0.8803	0.8803	0.8803	0.8803
PROB 6	0.0960	0.0905	0.0905	0.0905	0.0905	0.0905	0.0905	0.0905
PROB 7	0.0185	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174
BIT APPLIES	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500

Table 58 (Continued)

Depot Maintenance Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT MAINT=3	DEPOT MAINT=2.5	DEPOT MAINT=2	DEPOT MAINT=1.5	DEPOT MAINT=1	DEPOT MAINT=.5
FLT LN REPAIR	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
NEED PART	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
MAINT ACTION	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
GO TO HSC	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
RETURN TO FLT LN	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
PART ON PLL	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500
GO TO AMC	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
PART ON ASL	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
IN STK ASL	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500
RTN TO ACFT	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
GO TO PLL STOCK	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
IN STK PLL	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
CONTROL SUB	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000
GO TO ACFT	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
REMOVE PART	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
RTN TO OWN ACFT	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000
THEATER SEARCH	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000
PART IN THEATER	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
PART TO AMC	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000
REQ FM CONUS	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000
BIT APPLIES	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
AVERAGE TIME 1	0.6094	0.6094	[illegible]	0.6094	0.6094	0.6094	0.6094	0.6094
PROBABILITY 8	0.3000	0.2829	0.2829	0.2829	0.2829	0.2829	0.2829	0.2829

Table 58 (Continued)

Depot Maintenance Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT MAINT=3	DEPOT MAINT=2.5	DEPOT MAINT=2	DEPOT MAINT=1.5	DEPOT MAINT=1	DEPOT MAINT=.5
PROBABILITY 9	0.0510	0.0481	0.0481	0.0481	0.0481	0.0481	0.0481	0.0481
AVERAGE TIME 2	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
PROB HSC W/O PAR	0.1400	0.1162	0.1162	0.1162	0.1162	0.1162	0.1162	0.1162
TIME HSC W/O PAR	0.1820	0.1511	0.1511	0.1511	0.1511	0.1511	0.1511	0.1511
PROOF PROB	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
FLYING HOURS	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000
MTBEMA	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000
ELAPSED HOURS	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000
ACFT ASSIGNED	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000

Table 59

Depot Transit Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT TRANS =7	DEPOT TRANS =6	DEPOT TRANS =5	DEPOT TRANS =4	DEPOT TRANS =3	DEPOT TRANS =2	DEPOT TRANS =1	DEPOT TRANS =0
CAN ISOLATE	1.0000	0.9400	0.9400	0.9400	0.9400	0.9400	0.9400	0.9400	0.9400	0.9400
HARDWARE OK	1.0000	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
INDICATES GO	1.0000	0.9200	0.9200	0.9200	0.9200	0.9200	0.9200	0.9200	0.9200	0.9200
DEPOT TRANS TIME	8.0000	8.0000	7.0000	6.0000	5.0000	4.0000	3.0000	2.0000	1.0000	0.0000
DEPOT MAINT	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500	3.1500
PROBABILITY OF DEPOT	.0000	0.1699	0.1699	0.1699	0.1699	0.1699	0.1699	0.1699	0.1699	0.1699
TOTAL DEPOT TRANS	.0000	1.9191	1.7492	1.5793	1.4094	1.2396	1.0697	0.8998	0.7299	0.5601
TOTAL DEPOT MAINT	.0000	0.5916	0.5916	0.5916	0.5916	0.5916	0.5916	0.5916	0.5916	0.5916
TOTAL DEPOT TIME	.0000	2.5106	2.3408	2.1709	2.0010	1.8311	1.6612	1.4914	1.3215	1.1516
MTTR	0.5000	0.5795	0.5698	0.5601	0.5504	0.5407	0.5311	0.5214	0.5117	0.5020
AVERAGE DOWN TIME	5.5149	7.0886	6.9187	6.7489	6.5790	6.4091	6.2392	6.0694	5.8995	5.7296
AVAILABILITY	68.1682	59.0844	60.0650	61.0455	62.0260	63.0066	63.9871	64.9676	65.9482	66.9287
PROB DEPOT 1	.0000	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570
TRANS DEPOT 1	.0000	0.4560	0.3990	0.3420	0.2850	0.2280	0.1710	0.1140	0.0570	0.0000
MAINT DEPOT 1	.0000	0.1796	0.1796	0.1796	0.1796	0.1796	0.1796	0.1796	0.1796	0.1796
TOTAL DEPOT 1	.0000	0.6356	0.5786	0.5216	0.4646	0.4076	0.3506	0.2936	0.2366	0.1796
PROB DEPOT 2	.0000	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401
TRANS DEPOT 2	.0000	0.3211	0.2809	0.2408	0.2007	0.1605	0.1204	0.0803	0.0401	0.0000
MAINT DEPOT 2	.0000	0.1465	0.1465	0.1465	0.1465	0.1465	0.1465	0.1465	0.1465	0.1465
TOTAL DEPOT 2	.0000	0.4676	0.4274	0.3873	0.3472	0.3070	0.2669	0.2268	0.1866	0.1465
PROB DEPOT 3	.0000	0.0231	0.0231	0.0231	0.0231	0.0231	0.0231	0.0231	0.0231	0.0231
TRANS DEPOT 3	.0000	0.1846	0.1615	0.1385	0.1154	0.0923	0.0692	0.0462	0.0231	0.0000
MAINT DEPOT3	.0000	0.0842	0.0842	0.0842	0.0842	0.0842	0.0842	0.0842	0.0842	0.0842

Table 59 (Continued)

Depot Transit Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT TRANS =7	DEPOT TRANS =6	DEPOT TRANS =5	DEPOT TRANS =4	DEPOT TRANS =3	DEPOT TRANS =2	DEPOT TRANS =1	DEPOT TRANS =0
TOTAL DEPOT 3	.0000	0.2688	0.2458	0.2227	0.1996	0.1765	0.1535	0.1304	0.1073	0.0842
PROB DEPOT 4	.0000	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100
TRANS DEPOT 4	.0000	0.0853	0.0753	0.0652	0.0552	0.0452	0.0351	0.0251	0.0151	0.0050
MAINT DEPOT 4	.0000	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366
TOTAL DEPOT 4	.0000	0.1219	0.1119	0.1018	0.0918	0.0818	0.0717	0.0617	0.0517	0.0416
PROB DEPOT 5	.0000	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058
TRANS DEPOT 5	.0000	0.0490	0.0433	0.0375	0.0317	0.0260	0.0202	0.0144	0.0087	0.0029
MAINT DEPOT 5	.0000	0.0211	0.0211	0.0211	0.0211	0.0211	0.0211	0.0211	0.0211	0.0211
TOTAL DEPOT 5	.0000	0.0701	0.0643	0.0586	0.0528	0.0470	0.0413	0.0355	0.0297	0.0239
PROB DEPOT 6	.0000	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056
TRANS DEPOT 6	.0000	0.0534	0.0478	0.0423	0.0367	0.0312	0.0256	0.0201	0.0145	0.0089
MAINT DEPOT 6	.0000	0.0203	0.0203	0.0203	0.0203	0.0203	0.0203	0.0203	0.0203	0.0203
TOTAL DEPOT 6	.0000	0.0737	0.0681	0.0626	0.0570	0.0514	0.0459	0.0403	0.0348	0.0292
PROB DEPOT 7	.0000	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032
TRANS DEPOT 7	.0000	0.0307	0.0275	0.0243	0.0211	0.0179	0.0147	0.0115	0.0083	0.0051
MAINT DEPOT 7	.0000	0.0117	0.0117	0.0117	0.0117	0.0117	0.0117	0.0117	0.0117	0.0117
TOTAL DEPOT 7	.0000	0.0424	0.0392	0.0360	0.0328	0.0296	0.0264	0.0232	0.0200	0.0168
PROB DEPOT 8	.0000	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146
TRANS DEPOT 8	.0000	0.1360	0.1213	0.1067	0.0921	0.0775	0.0629	0.0482	0.0336	0.0190
MAINT DEPOT8	.0000	0.0534	0.0534	0.0534	0.0534	0.0534	0.0534	0.0534	0.0534	0.0534
TOTAL DEPOT 8	.0000	0.1893	0.1747	0.1601	0.1455	0.1309	0.1162	0.1016	0.0870	0.0724
PROB DEPOT 9	.0000	0.0084	0.0084	0.0084	0.0084	0.0084	0.0084	0.0084	0.0084	0.0084
TRANS DEPOT 9	.0000	0.0782	0.0698	0.0614	0.0530	0.0446	0.0361	0.0277	0.0193	0.0109

Table 59 (Continued)

Depot Transit Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT TRANS =7	DEPOT TRANS =6	DEPOT TRANS =5	DEPOT TRANS =4	DEPOT TRANS =3	DEPOT TRANS =2	DEPOT TRANS =1	DEPOT TRANS =0
MAINT DEPOT 9	.0000	0.0307	0.0307	0.0307	0.0307	0.0307	0.0307	0.0307	0.0307	0.0307
TOTAL DEPOT 9	.0000	0.1089	0.1005	0.0921	0.0836	0.0752	0.0668	0.0584	0.0500	0.0416
PROB DEPOT 10	.0000	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
TRANS DEPOT 10	.0000	0.1236	0.1226	0.1217	0.1207	0.1198	0.1188	0.1179	0.1169	0.1160
MAINT DEPOT 10	.0000	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035
TOTAL DEPOT 10	.0000	0.1271	0.1261	0.1252	0.1242	0.1233	0.1223	0.1214	0.1204	0.1194
PROB DEPOT 11	.0000	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
TRANS DEPOT 11	.0000	0.0711	0.0705	0.0700	0.0694	0.0689	0.0683	0.0678	0.0672	0.0667
MAINT DEPOT 11	.0000	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
TOTAL DEPOT 11	.0000	0.0731	0.0725	0.0720	0.0714	0.0709	0.0703	0.0698	0.0692	0.0687
PROB DEPOT 12	.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
TRANS DEPOT 12	.0000	0.2083	0.2080	0.2078	0.2076	0.2073	0.2071	0.2068	0.2066	0.2064
MAINT DEPOT 12	.0000	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009
TOTAL DEPOT 12	.0000	0.2091	0.2089	0.2087	0.2084	0.2082	0.2079	0.2077	0.2075	0.2072
PROB DEPOT 13	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
TRANS DEPOT 13	.0000	0.1198	0.1196	0.1195	0.1193	0.1192	0.1191	0.1189	0.1188	0.1187
MAINT DEPOT 13	.0000	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
TOTAL DEPOT 13	.0000	0.1203	0.1201	0.1200	0.1198	0.1197	0.1196	0.1194	0.1193	0.1192
PROB DEPOT 14	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
TRANS DEPOT 14	.0000	0.0014	0.0012	0.0011	0.0010	0.0008	0.0007	0.0006	0.0004	0.0003
MAINT DEPOT 14	.0000	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
TOTAL DEPOT 14	.0000	0.0018	0.0017	0.0016	0.0015	0.0013	0.0012	0.0011	0.0009	0.0008
PROB DEPOT 15	.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Table 59 (Continued)

Depot Transit Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT TRANS =7	DEPOT TRANS =6	DEPOT TRANS =5	DEPOT TRANS =4	DEPOT TRANS =3	DEPOT TRANS =2	DEPOT TRANS =1	DEPOT TRANS =0
TRANS DEPOT 15	.0000	0.0008	0.0007	0.0006	0.0006	0.0005	0.0004	0.0003	0.0003	0.0002
MAINT DEPOT 15	.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
TOTAL DEPOT 15	.0000	0.0011	0.0010	0.0009	0.0008	0.0008	0.0007	0.0006	0.0005	0.0005
PROB FLT LN REPAIR	0.5600	0.4649	0.4649	0.4649	0.4649	0.4649	0.4649	0.4649	0.4649	0.4649
TIME FLT LN RPR	0.2800	0.2324	0.2324	0.2324	0.2324	0.2324	0.2324	0.2324	0.2324	0.2324
PROB PART FROM PLL	0.2040	0.1693	0.1693	0.1693	0.1693	0.1693	0.1693	0.1693	0.1693	0.1693
TIME PART FROM PLL	0.4284	0.3556	0.3556	0.3556	0.3556	0.3556	0.3556	0.3556	0.3556	0.3556
PROB PART FROM ASL	0.0775	0.0644	0.0644	0.0644	0.0644	0.0644	0.0644	0.0644	0.0644	0.0644
TIME PART FROM ASL	0.1868	0.1550	0.1550	0.1550	0.1550	0.1550	0.1550	0.1550	0.1550	0.1550
PROB PART FROM THEAT	0.0133	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110
TIME PART FROM THEAT	1.6287	1.3520	1.3520	1.3520	1.3520	1.3520	1.3520	1.3520	1.3520	1.3520
PROB PART FROM CONUS	0.0033	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028
TIME PART FROM CONUS	2.8032	2.3270	2.3270	2.3270	2.3270	2.3270	2.3270	2.3270	2.3270	2.3270
PROB CONTROL SUB	0.0018	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
TIME CONTROL SUB	0.0057	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
PROB 1	1.0000	0.9430	0.9430	0.9430	0.9430	0.9430	0.9430	0.9430	0.9430	0.9430
PROB 2	0.1400	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
PROB 3	.0000	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760
PROB 4	.0000	0.0437	0.0437	0.0437	0.0437	0.0437	0.0437	0.0437	0.0437	0.0437
PROB 5	1.0000	0.8803	0.8803	0.8803	0.8803	0.8803	0.8803	0.8803	0.8803	0.8803
PROB 6	0.0960	0.0905	0.0905	0.0905	0.0905	0.0905	0.0905	0.0905	0.0905	0.0905
PROB 7	0.0185	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174
BIT APPLIES	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500

Table 59 (Continued)

Depot Transit Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT TRANS =7	DEPOT TRANS =6	DEPOT TRANS =5	DEPOT TRANS =4	DEPOT TRANS =3	DEPOT TRANS =2	DEPOT TRANS =1	DEPOT TRANS =0
FLT LN REPAIR	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
NEED PART	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
MAINT ACTION	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
GO TO HSC	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
RETURN TO FLT LN	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
PART ON PLL	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500
GO TO AMC	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
PART ON ASL	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
IN STK ASL	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500
RTN TO ACFT	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
GO TO PLL STOCK	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
IN STK PLL	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
CONTROL SUB	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000
GO TO ACFT	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
REMOVE PART	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
RTN TO OWN ACFT	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000	0.6000
THEATER SEARCH	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000
PART IN THEATER	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
PART TO AMC	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000	96.0000
REQ FM CONUS	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000	840.0000
BIT APPLIES	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500
AVERAGE TIME 1	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094
PROBABILITY 8	0.3000	0.2829	0.2829	0.2829	0.2829	0.2829	0.2829	0.2829	0.2829	0.2829

Table 59 (Continued)

Depot Transit Time

EVENT/EXCURSION	PERFECT BIT	BASE	DEPOT TRANS =7	DEPOT TRANS =6	DEPOT TRANS =5	DEPOT TRANS =4	DEPOT TRANS =3	DEPOT TRANS =2	DEPOT TRANS =1	DEPOT TRANS =0
PROBABILITY 9	0.0510	0.0481	0.0481	0.0481	0.0481	0.0481	0.0481	0.0481	0.0481	0.0481
AVERAGE TIME 2	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
PROB HSC W/O PART	0.1400	0.1162	0.1162	0.1162	0.1162	0.1162	0.1162	0.1162	0.1162	0.1162
TIME HSC W/O PART	0.1820	0.1511	0.1511	0.1511	0.1511	0.1511	0.1511	0.1511	0.1511	0.1511
PROOF PROB	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
FLYING HOURS	480.0000	480.0000	480.0000	480.0000	480.0000	480.0000	460.0000	480.0000	480.0000	480.0000
MTBEMA	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000	4.5000
ELAPSED HOURS	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000	168.0000
ACFT ASSIGNED	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000

Unit Training Model Instructions

Introduction

The unit training model was used to investigate alternative unit training schedules for LHX units. The schedules were evaluated in terms of their ability to effectively use the required training resources and to provide the maximum number of fully mission capable units with the shortest possible down time. The fielding schedule, training resources, and training requirements were inputs to the model. The model then determined the distribution of resources over the training period. Iterative applications of the model were used in which individual training schedules were modified to level the resource distributions. The resource leveling was performed in an attempt to more effectively utilize available resources without impacting on the overall accomplishment of the training. The model was applied to four alternative training schedules. The alternative schedules were developed by varying the location of the training from home stations to area training centers, pre-positioning equipment, or eliminating training Phases I and III (Individual and Crew and Gunnery training, respectively).

Hardware and Software Requirements

The unit training model requires an Apple Macintosh Plus computer to run. It employs Microsoft Basic version 2.00 (Decimal Math), 1984. A hard disk or 720K micro diskettes must be available in order to save individual runs of the model. In order to obtain hard copy output data from the model, an Apple compatible printer must be available.

Getting Started

To run the Unit training Model, the correct version of Microsoft Basic must be loaded. Once Microsoft Basic is loaded, the user should perform the following.

SELECT OPTION	ACTION
FILE	To invoke the File options menu
OPEN	To open the model
DRIVE	To change to the disk drive where the model is stored (if necessary)
PRIME	To open the primary program module

SELECT OPTION	ACTION
RUN	To invoke the Run options menu
START	To begin running the model

At this point the first logo of the unit training model will appear. The user should follow the directions as they appear on the screen.

In order to stop the program at any point, the following steps should be performed.

SELECT OPTION	ACTION
RUN	To invoke the Run options menu
STOP	To stop running the program
FILE	To invoke the File options menu
CLOSE	To close the primary program module

The user should then follow the normal shutdown procedures to quit Microsoft Basic and return to the Macintosh operating system.

Using the Unit Training Model

When the logo screen of the model is in view, the user should follow the directions on the screen to strike any key or click the mouse to continue. The next screen that appears is the main program menu. This menu contains the following options:

LHX Transition Plan Program

Set Up, Change, or Manipulate Data

Redimension a File

Combine Resource Expenditures

Combine Training Commitment

Any one of these menu options may be initiated by placing the cursor over the option and clicking on the mouse. Other options on the screen include "Restore Cursor," "Stop," and "Quit." "Restore Cursor" will refresh the screen and will

restore the spindle cursor. "Stop" will stop the program. In order to restart the program, the user must open the "Run" menu and select either "Start" of "Continue." "Quit" will exit the Transition Training Program and Microsoft Basic and return the user to the Macintosh operating system.

LHX Transition Plan Program. This program module allows the user to input or load an existing unit training plan. Included are the numbers and types of units requiring training and the fielding schedule associated with units.

At some time since the development of the model, the original file associated with the program module has become damaged. The file is provided and a listing of the code may be generated. However, when the module is called by the "Primary" program, a "Device I/O Error" occurs and prevents the user from executing the program.

Set Up, Change, or Manipulate Data. This menu option executes the Transition Training Resource Definition module which allows the user to develop an input file or load an existing resource file. The input file includes resource data, training phases, phase sequence, and resources required per phase.

Redimension a File. This menu option executes the Transition Training Redimension module which allows the user to change an existing resource file. Options include adding or deleting resources, phases, cost types, and resource packages.

Combine Resource Expenditures. This executes the Resource Requirements Combiner which allows the user to generate, display, and save resource distribution graphs and resource loading charts based on a particular training schedule and its associated resources.

Combine Training Commitment. This menu options executes the Package Scheduling Combiner which allows the user to develop, display, and save Gantt charts displaying the training schedule by phase for each unit of the alternative under investigation. It also calculates the average unit readiness down time and the average time to new equipment readiness.

Upon selection of one of the training program modules, except "LHX Transition Plan Program," the logo screen for the module appears. Instructions for each module are provided on the subsequent screens to include: input of data files, reading existing files, and saving and printing outputs.

Inputs

The following pages present a consolidation of the input data extracted from the LHX Distribution Plan. They contain a listing by year of the units scheduled to receive LHX aircraft, their parent unit, the number and type of aircraft they are to

receive and deployment area. All units are identified by code containing the year of receipt, type aircraft, and sequence distribution. All deployment areas are referenced by number such as Area 1, 2, or 3.

Figure 2 illustrates the resource packages identified for each of the different LHX missions. A total of 19 resource packages were identified for LHX units performing attack missions. a total of 20 resource packages were identified for units performing utility missions. An examination of predecessor system documents revealed that training for units performing reconnaissance mission requires the same resources as training for units performing attack missions. The same is true for utility and medevac units. Therefore the training outlines for attack units and utility units were applied equally to reconnaissance units and medevac units respectively.

Outputs

The outputs of the model are given in the form of Gantt charts, tables, and resource graphs. Specific outputs for each alternative are:

1. A training schedule before and after resource leveling analyses.

2. A table displaying the training start time, completion time, and duration for each unit.

3. Graphs illustrating the critical resource distributions.

Unit Input Data for FY 1996

UNIT	PARENT	AREA	TYPE A/C	NUMBER REQUIRED	SEQUENCE	MISSION
96-1R	96-A	Area 3	SCAT	10	S1	RECON
96-2R	96-A	Area 3	SCAT	10	S2	RECON
96-3U	96-3	Area 3	UTILITY	6	U1	UTILITY

Unit Input Data for FY 1997
(Continued)

UNIT	PARENT	AREA	TYPE A/C	NUMBER REQUIRED	SEQUENCE	MISSION
97-1A	97-A	Area 3	SCAT	12	S3	ATTACK
97-2A	97-A	Area 3	SCAT	11	S4	ATTACK
97-3A	97-A	Area 3	SCAT	11	S5	ATTACK
97-4A	97-B	Area 4	SCAT	12	S6	ATTACK
97-5U	97-B	Area 4	UTILITY	17	U2	UTILITY

Unit Input Data for FY 1998
(Continued)

UNIT	PARENT	AREA	TYPE A/C	NUMBER REQUIRED	SEQUENCE	MISSION
98-1A	98-A	Area 1	SCAT	12	S7	ATTACK
98-2A	98-A	Area 1	SCAT	11	S8	ATTACK
98-3A	98-A	Area 1	SCAT	11	S9	ATTACK
98-4R	98-B	Area 1	SCAT	10	S10	RECON
98-5R	98-B	Area 1	SCAT	10	S11	RECON
98-6U	98-6	Area 1	UTILITY	6	U3	UTILITY
98-7A	98-C	Area 2	SCAT	12	S12	ATTACK
98-8A	98-C	Area 2	SCAT	11	S13	ATTACK
98-9A	98-C	Area 2	SCAT	11	S14	ATTACK
98-10U	98-10	Area 2	UTILITY	6	U4	UTILITY
98-11U	98-11	Area 2	UTILITY	12	U5	UTILITY
98-12U	98-12	Area 2	UTILITY	15	U6	UTILITY
98-13U	98-13	Area 2	UTILITY	15	U7	UTILITY
98-14U	98-14	Area 2	UTILITY	15	U8	UTILITY
98-15U	98-15	Area 2	UTILITY	2	U9	UTILITY

Unit Input Data for FY 1999
(Continued)

UNIT	PARENT	AREA	TYPE A/C	NUMBER REQUIRED	SEQUENCE	MISSION
99-1R	99-A	Area 2	SCAT	10	S15	RECON
99-2R	99-A	Area 2	SCAT	10	S16	RECON
99-3A	99-B	Area 2	SCAT	12	S17	ATTACK
99-4A	99-B	Area 2	SCAT	11	S18	ATTACK
99-5A	99-B	Area 2	SCAT	11	S19	ATTACK
99-6R	99-C	Area 2	SCAT	10	S20	RECON
99-7R	99-C	Area 2	SCAT	10	S21	RECON
99-8R	99-C	Area 2	SCAT	10	S22	RECON
99-9A	99-D	Area 2	SCAT	12	S23	ATTACK
99-10A	99-D	Area 2	SCAT	11	S24	ATTACK
99-11A	99-D	Area 2	SCAT	11	S25	ATTACK
99-12A	99-E	Area 2	SCAT	12	S26	ATTACK
99-13A	99-E	Area 2	SCAT	11	S27	ATTACK
99-14A	99-E	Area 2	SCAT	11	S28	ATTACK
99-15A	99-F	Area 2	SCAT	12	S29	ATTACK
99-16A	99-F	Area 2	SCAT	11	S30	ATTACK
99-17A	99-F	Area 2	SCAT	11	S31	ATTACK
99-18R	99-G	Area 2	SCAT	10	S32	RECON
99-19R	99-G	Area 2	SCAT	10	S33	RECON
99-20R	99-G	Area 2	SCAT	10	S34	RECON
99-21R	99-G	Area 2	SCAT	10	S35	RECON
99-22M	99-22	Area 2	UTILITY	15	U10	MEDEVAC
99-23U	99-23	Area 3	UTILITY	16	U11	UTILITY
99-24U	99-24	Area 2	UTILITY	12	U12	UTILITY
99-25M	99-25	Area 2	UTILITY	15	U13	MEDEVAC
99-26M	99-26	Area 2	UTILITY	15	U14	MEDEVAC
99-27M	99-27	Area 2	UTILITY	15	U15	MEDEVAC
99-28M	99-28	Area 2	UTILITY	15	U16	MEDEVAC
99-29M	99-29	Area 2	UTILITY	15	U17	MEDEVAC

Unit Input Data for FY 2000
(Continued)

UNIT	PARENT	AREA	TYPE A/C	NUMBER REQUIRED	SEQUENCE	MISSION
00-1U	00-A	Area 2	UTILITY	15	U18	UTILITY
00-2U	00-A	Area 2	UTILITY	15	U19	UTILITY
00-3U	00-A	Area 2	UTILITY	15	U20	UTILITY
00-4U*	00-B	Area 2	UTILITY	1	U21	UTILITY*
00-5U*	00-B	Area 2	UTILITY	1	U22	UTILITY*
00-6U*	00-B	Area 2	UTILITY	1	U23	UTILITY*
00-7R	00-C	Area 2	SCAT	10	S36	RECON
00-8R	00-C	Area 2	SCAT	10	S37	RECON
00-9R	00-C	Area 2	SCAT	10	S38	RECON
00-10R	00-C	Area 2	SCAT	10	S39	RECON
00-11A	00-D	Area 6	SCAT	12	S40	ATTACK
00-12A	00-D	Area 6	SCAT	11	S41	ATTACK
00-13A	00-D	Area 6	SCAT	11	S42	ATTACK
00-14R	00-E	Area 6	SCAT	10	S43	RECON
00-15R	00-E	Area 6	SCAT	10	S44	RECON
00-16R	00-E	Area 6	SCAT	10	S45	RECON
00-17U	00-17	Area 6	UTILITY	12	U24	UTILITY
00-18U	00-18	Area 6	UTILITY	10	U25	UTILITY
00-19U*	00-19	Area 6	UTILITY	1	U26	UTILITY*
00-20U*	00-20	Area 6	UTILITY	1	U27	UTILITY*
00-21U*	00-21	Area 6	UTILITY	2	U28	UTILITY*
00-22M	00-22	Area 6	UTILITY	15	U29	MEDEVAC
00-23M	00-23	Area 6	UTILITY	15	U30	MEDEVAC
00-24A	00-F	Area 3	SCAT	12	S46	ATTACK
00-25A	00-F	Area 3	SCAT	11	S47	ATTACK
00-26A	00-F	Area 3	SCAT	11	S48	ATTACK
00-27R	00-G	Area 3	SCAT	10	S49	RECON
00-28R	00-G	Area 3	SCAT	10	S50	RECON
00-29R	00-H	Area 4	SCAT	10	S51	RECON
00-30R	00-H	Area 4	SCAT	10	S52	RECON
00-31A	00-H	Area 4	SCAT	11	S53	ATTACK
00-32A	00-H	Area 4	SCAT	11	S54	ATTACK
00-33A	00-G	Area 4	SCAT	11	S55	ATTACK
00-34R	00-I	Area 4	SCAT	10	S56	RECON
00-35R	00-I	Area 4	SCAT	10	S57	RECON
00-36U	00-36	Area 4	UTILITY	12	U31	UTILITY
00-37R	00-J	Area 4	SCAT	10	S58	RECON
00-38R	00-J	Area 4	SCAT	10	S59	RECON
00-39U	00-39	Area 4	UTILITY	12	U32	UTILITY
00-40R	00-K	Area 4	SCAT	10	S60	RECON
00-41R	00-K	Area 4	SCAT	10	S61	RECON

Unit Input Data for FY 2001
(Continued)

UNIT	PARENT	AREA	TYPE A/C	NUMBER REQUIRED	SEQUENCE	MISSION
01-1R	01-A	Area 4	SCAT	10	S62	RECON
01-2R	01-A	Area 4	SCAT	10	S63	RECON
01-3U	01-3	Area 4	UTILITY	12	U33	UTILITY
01-4U	01-B	Area 4	UTILITY	15	U34	UTILITY
01-5U	01-B	Area 4	UTILITY	15	U35	UTILITY
01-6U	01-B	Area 4	UTILITY	15	U36	UTILITY
01-7U*	01-7	Area 4	UTILITY	2	U37	UTILITY*
01-8R	01-C	Area 4	SCAT	10	S64	RECON
01-9R	01-C	Area 4	SCAT	10	S65	RECON
01-10U	01-10	Area 4	UTILITY	12	U38	UTILITY
01-11R	01-D	Area 3	SCAT	10	S66	RECON
01-12R	01-D	Area 3	SCAT	10	S67	RECON
01-13U	01-13	Area 3	UTILITY	12	U39	UTILITY
01-14A	01-E	Area 4	SCAT	11	S68	ATTACK
01-15A	01-E	Area 4	SCAT	11	S69	ATTACK
01-16A	01-E	Area 4	SCAT	11	S70	ATTACK
01-17R	01-E	Area 4	SCAT	10	S71	RECON
01-18R	01-E	Area 4	SCAT	10	S72	RECON
01-19R	01-F	Area 4	SCAT	10	S73	RECON
01-20R	01-F	Area 4	SCAT	10	S74	RECON
01-21U	01-21	Area 4	UTILITY	12	U40	UTILITY
01-22U	01-22	Area 5	UTILITY	6	41	UTILITY
01-23A	01-G	Area 5	SCAT	12	S75	ATTACK
01-24A	01-G	Area 5	SCAT	11	S76	ATTACK
01-25A	01-G	Area 5	SCAT	11	S77	ATTACK
01-26R	01-H	Area 5	SCAT	10	S78	RECON
01-27R	01-H	Area 5	SCAT	10	S79	RECON
01-28A	01-I	Area 3	SCAT	11	S80	ATTACK
01-29A	01-I	Area 3	SCAT	11	S81	ATTACK
01-30A	01-I	Area 3	SCAT	11	S82	ATTACK
01-31R	01-I	Area 3	SCAT	10	S83	RECON
01-32R	01-I	Area 3	SCAT	10	S84	RECON
01-33U	01-J	Area 4	UTILITY	15	U42	UTILITY
01-34U	01-J	Area 4	UTILITY	15	U43	UTILITY
01-35U	01-J	Area 4	UTILITY	15	U44	UTILITY
01-36U*	01-36	Area 4	UTILITY	3	U45	UTILITY*
01-37U*	01-37	Area 4	UTILITY	10	U46	UTILITY*

Unit Input Data for FY 2002
(Continued)

UNIT	PARENT	AREA	TYPE A/C	NUMBER REQUIRED	SEQUENCE	MISSION
02-1R	02-A	Area 2	SCAT	10	S85	RECON
02-2R	02-A	Area 2	SCAT	10	S86	RECON
02-3U	02-3	Area 2	UTILITY	12	U47	UTILITY
02-4R	02-B	Area 3	SCAT	10	S87	RECON
02-5R	02-B	Area 3	SCAT	10	S88	RECON
02-6U	02-6	Area 3	UTILITY	12	U48	UTILITY
02-7U	02-C	Area 3	UTILITY	15	U49	UTILITY
02-8U	02-C	Area 3	UTILITY	15	U50	UTILITY
02-9U	02-C	Area 3	UTILITY	15	U51	UTILITY
02-10U*	02-10	Area 3	UTILITY	1	U52	UTILITY*
02-11U*	02-11	Area 3	UTILITY	1	U53	UTILITY*
02-12U*	02-12	Area 3	UTILITY	1	U54	UTILITY*
02-13U*	02-13	Area 3	UTILITY	1	U55	UTILITY*
02-14M	02-14	Area 3	UTILITY	15	U56	MEDEVAC
02-15M	02-15	Area 3	UTILITY	15	U57	MEDEVAC
02-16M	02-16	Area 3	UTILITY	15	U58	MEDEVAC
02-17M	02-17	Area 3	UTILITY	15	U59	MEDEVAC
02-18M	02-18	Area 3	UTILITY	15	U60	MEDEVAC
02-19M	02-19	Area 3	UTILITY	15	U61	MEDEVAC
02-20M	02-20	Area 3	UTILITY	15	U62	MEDEVAC
02-21M	02-C	Area 2	SCAT	11	S89	ATTACK
02-22A	02-C	Area 2	SCAT	11	S90	ATTACK
02-23A	02-C	Area 2	SCAT	11	S91	ATTACK
02-24R	02-C	Area 2	SCAT	10	S92	RECON
02-25R	02-C	Area 2	SCAT	10	S93	RECON
02-26R	02-D	Area 3	SCAT	10	S94	RECON
02-27R	02-D	Area 3	SCAT	10	S95	RECON
02-28U	02-28	Area 3	UTILITY	12	U63	UTILITY
02-29R	02-E	Area 2	SCAT	10	S96	RECON
02-30R	02-E	Area 2	SCAT	10	S97	RECON
02-31U	02-31	Area 2	UTILITY	12	U64	UTILITY
02-32A	02-F	Area 2	SCAT	12	S98	ATTACK
02-33A	02-F	Area 2	SCAT	11	S99	ATTACK
02-34A	02-F	Area 2	SCAT	11	S100	ATTACK
02-35A	02-G	Area 2	SCAT	12	S101	ATTACK
02-36A	02-G	Area 2	SCAT	11	S102	ATTACK
02-37A	02-G	Area 2	SCAT	11	S103	ATTACK

Unit Input Data for FY 2003
(Continued)

UNIT	PARENT	AREA	TYPE A/C	NUMBER REQUIRED	SEQUENCE	MISSION
03-1U	03-1	Area 2	UTILITY	6	U65	UTILITY
03-2R	03-A	Area 2	SCAT	10	S104	RECON
03-3R	03-A	Area 2	SCAT	10	S105	RECON
03-4U	03-4	Area 2	UTILITY	6	U66	UTILITY
03-5R	03-B	Area 2	SCAT	10	S106	RECON
03-6R	03-B	Area 2	SCAT	10	S107	RECON
03-7U	03-7	Area 2	UTILITY	6	U67	UTILITY
03-8A	03-C	Area 2	SCAT	12	S108	ATTACK
03-9A	03-C	Area 2	SCAT	11	S109	ATTACK
03-10A	03-C	Area 2	SCAT	11	S110	ATTACK
03-11R	03-D	Area 2	SCAT	10	S111	RECON
03-12R	03-D	Area 2	SCAT	10	S112	RECON
03-13U	03-13	Area 2	UTILITY	6	U68	UTILITY
03-14A	03-E	Area 2	SCAT	12	S113	ATTACK
03-15A	03-E	Area 2	SCAT	11	S114	ATTACK
03-16A	03-E	Area 2	SCAT	11	S114	ATTACK
03-17R	03-F	Area 2	SCAT	10	S116	RECON
03-18R	03-F	Area 2	SCAT	10	S117	RECON

MANEUVER AREA	MILES/ AGES
CLASSROOM/ BRIEFING ROOMS	DUMMY HELLFIRE
AIRFIELD/ STAGEFIELD	DUMMY STINGER
GARRISON FACILITIES	ATGM SYSTEM
AERIAL GUNNERY RANGE	FLYING HOURS
OPFOR	EXTERNAL AIRCRAFT
FRIENDLY FORCES	EXTERNAL TOE EQUIPMENT
EVALUATORS	MAINTENANCE
INTEGRATED SCAT TRAINING SYSTEM	SUPPLY
	TACTICAL TEAM TRAINER

REQUIRED RESOURCES IDENTIFIED FOR
LHX ATTACK/ RECONNAISANCE MISSIONS

MANEUVER AREA	MILES/ AGES
CLASSROOM/ BRIEFING ROOMS	DUMMY HELLFIRE
AIRFIELD/ STAGEFIELD	ARTILLERY GUNNERY RANGE
GARRISON FACILITIES	ATGM SYSTEM
DOOR GUNNERY RANGE	FLYING HOURS
OPFOR	EXTERNAL AIRCRAFT
FRIENDLY FORCES	EXTERNAL TOE EQUIPMENT
EVALUATORS	MAINTENANCE
INTEGRATED UTILITY TRAINING SYSTEM	SUPPLY
RCMAT	TACTICAL TEAM TRAINER

REQUIRED RESOURCES IDENTIFIED FOR
LHX UTILITY/ MEDEVAC MISSIONS

Figure 2. Resources required for LHX.

Unit Training Model Outputs

The following pages contain the summary outputs for the alternative training schedules examined in the unit training research effort. For each alternative, two sets of output data are provided. First, output data are given prior to deconfliction analyses. Outputs are also provided for each alternative after resource distributions have been leveled, where possible.

For each alternative, the following information is provided.

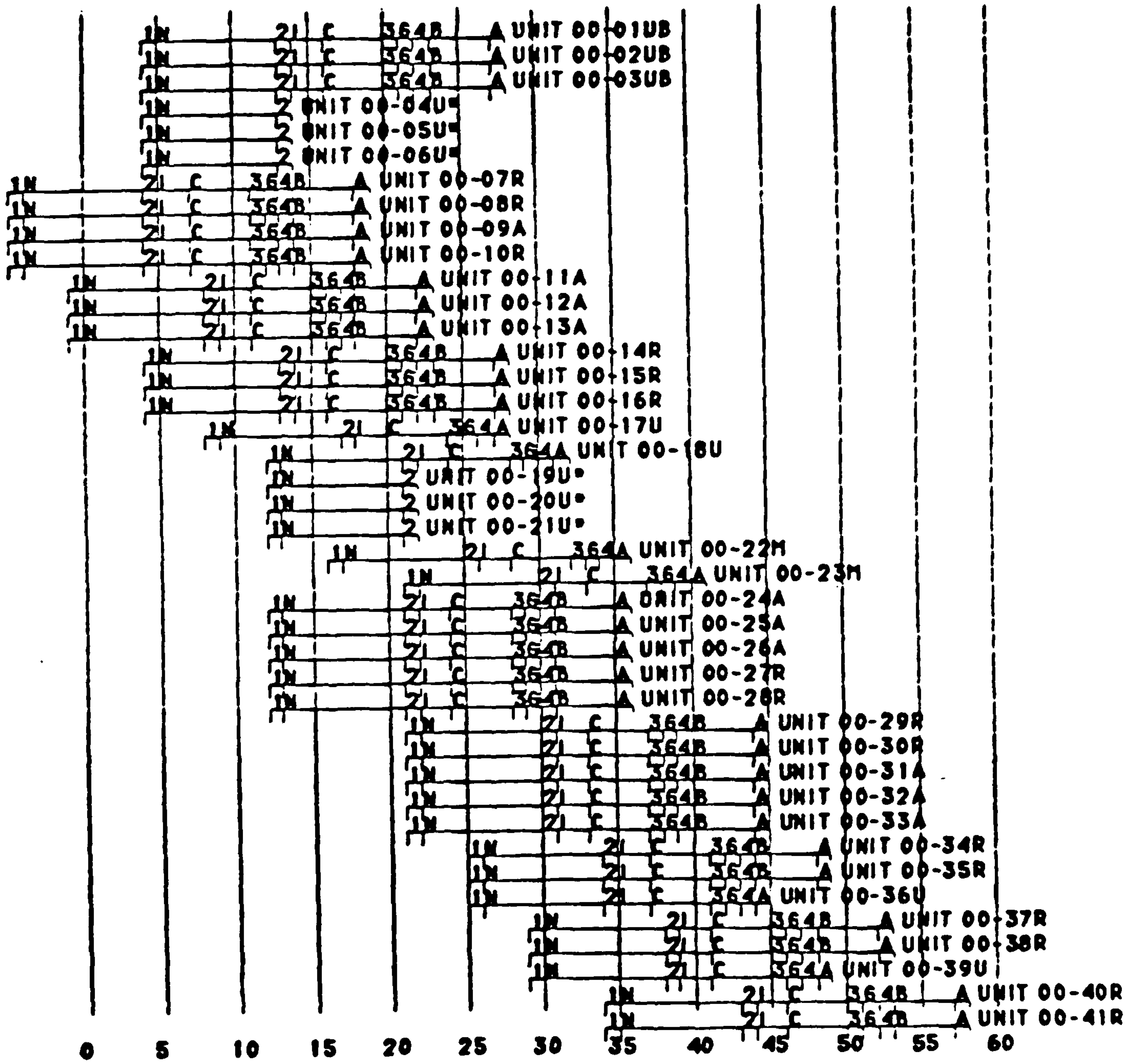
1. A training schedule before and after resource leveling.

2. A table displaying the training start time, completion time and duration for each unit.

3. Graphs illustrating the critical resource distributions.

BASELINE CASE PRIOR
TO DECONFLICTION ANALYSES

TRAINING SCHEDULE

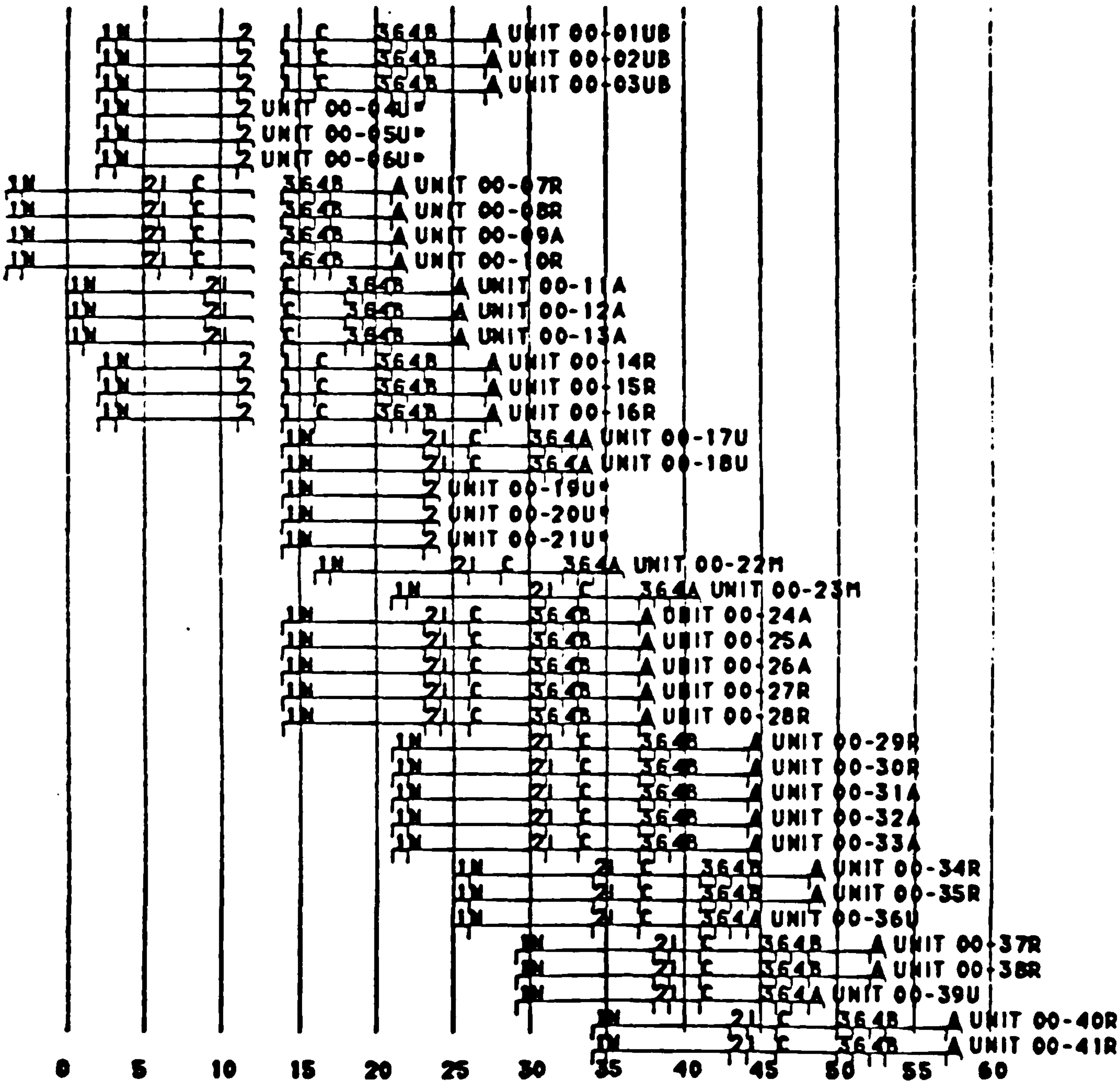


UNIT TRAINING TIMES

Unit	Week Start	Week End	Duration In Weeks
UNIT 00-01UB	4	28	24
UNIT 00-02UB	4	28	24
UNIT 00-03UB	4	28	24
UNIT 00-04U*	4	14	10
UNIT 00-05U*	4	14	10
UNIT 00-06U*	4	14	10
UNIT 00-07R	-5	19	24
UNIT 00-08R	-5	19	24
UNIT 00-09A	-5	19	24
UNIT 00-10R	-5	19	24
UNIT 00-11A	-1	23	24
UNIT 00-12A	-1	23	24
UNIT 00-13A	-1	23	24
UNIT 00-14R	4	28	24
UNIT 00-15R	4	28	24
UNIT 00-16R	4	28	24
UNIT 00-17U	8	28	20
UNIT 00-18U	12	32	20
UNIT 00-19U*	12	22	10
UNIT 00-20U*	12	22	10
UNIT 00-21U*	12	22	10
UNIT 00-22M	16	36	20
UNIT 00-23M	21	41	20
UNIT 00-24A	12	36	24
UNIT 00-25A	12	36	24
UNIT 00-26A	12	36	24
UNIT 00-27R	12	36	24
UNIT 00-28R	12	36	24
UNIT 00-29R	21	45	24
UNIT 00-30R	21	45	24
UNIT 00-31A	21	45	24
UNIT 00-32A	21	45	24
UNIT 00-33A	21	45	24
UNIT 00-34R	25	49	24
UNIT 00-35R	25	49	24
UNIT 00-36U	25	45	20
UNIT 00-37R	29	53	24
UNIT 00-38R	29	53	24
UNIT 00-39U	29	49	20
UNIT 00-40R	34	58	24
UNIT 00-41R	34	58	24

Average Unit Readiness Downtime is 21.4 weeks
Average time to new equipment readiness is 33.6 weeks

TRAINING SCHEDULE REALIGNED
FOR CHRISTMAS HOLIDAYS



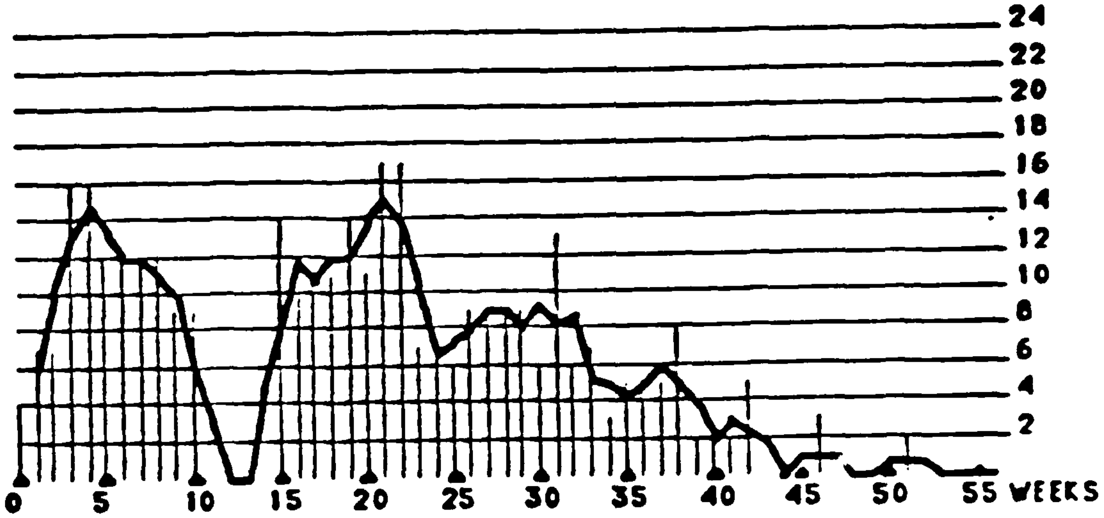
UNIT TRAINING TIMES REALIGNED
FOR CHRISTMAS HOLIDAYS

Unit	Week Start	Week End	Duration In Weeks
UNIT 00-01UB	2	28	26
UNIT 00-02UB	2	28	26
UNIT 00-03UB	2	28	26
UNIT 00-04U*	2	12	10
UNIT 00-05U*	2	12	10
UNIT 00-06U*	2	12	10
UNIT 00-07R	-4	22	26
UNIT 00-08R	-4	22	26
UNIT 00-09A	-4	22	26
UNIT 00-10R	-4	22	26
UNIT 00-11A	0	26	26
UNIT 00-12A	0	26	26
UNIT 00-13A	0	26	26
UNIT 00-14R	2	28	26
UNIT 00-15R	2	28	26
UNIT 00-16R	2	28	26
UNIT 00-17U	14	34	20
UNIT 00-18U	14	34	20
UNIT 00-19U*	14	24	10
UNIT 00-20U*	14	24	10
UNIT 00-21U*	14	24	10
UNIT 00-22M	16	36	20
UNIT 00-23M	21	41	20
UNIT 00-24A	14	38	24
UNIT 00-25A	14	38	24
UNIT 00-26A	14	38	24
UNIT 00-27R	14	38	24
UNIT 00-28R	14	38	24
UNIT 00-29R	21	45	24
UNIT 00-30R	21	45	24
UNIT 00-31A	21	45	24
UNIT 00-32A	21	45	24
UNIT 00-33A	21	45	24
UNIT 00-34R	25	49	24
UNIT 00-35R	25	49	24
UNIT 00-36U	25	45	20
UNIT 00-37R	29	53	24
UNIT 00-38R	29	53	24
UNIT 00-39U	29	49	20
UNIT 00-40R	34	58	24
UNIT 00-41R	34	58	24

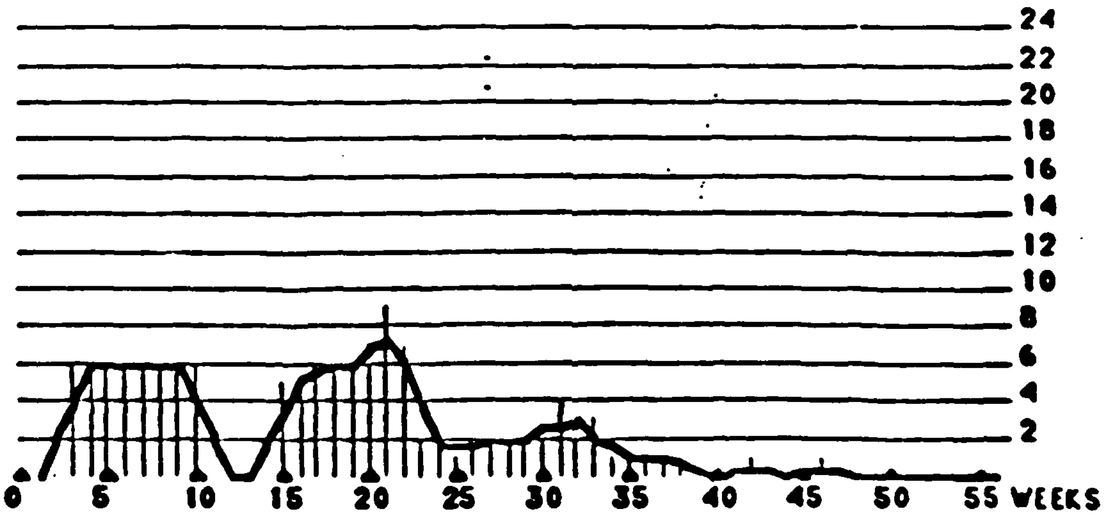
Average Unit Readiness Downtime is 22 weeks
Average time to new equipment readiness is 34.5 weeks

CRITICAL RESOURCE DISTRIBUTIONS
FOR BASELINE CASE

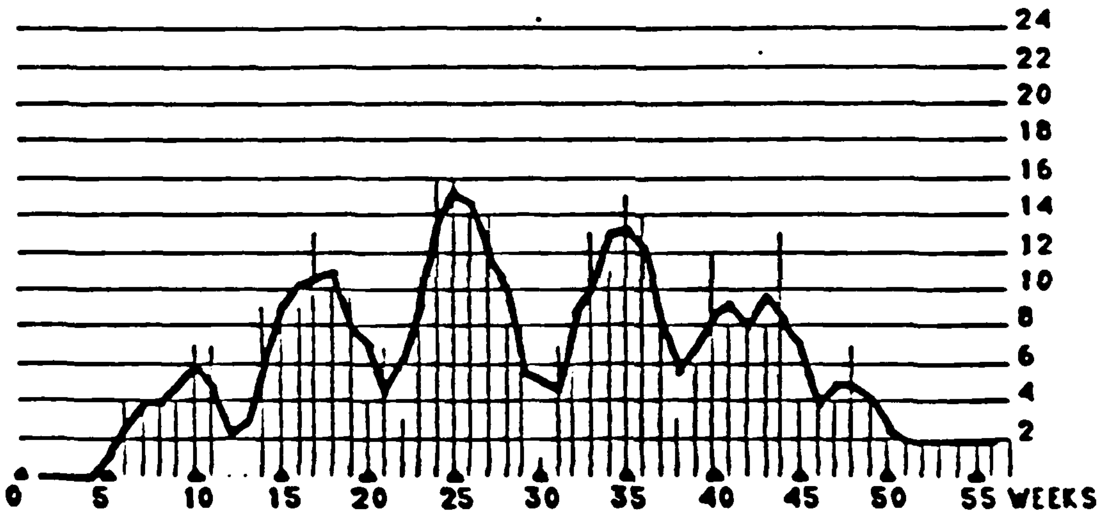
AERIAL GUNNERY RANGE



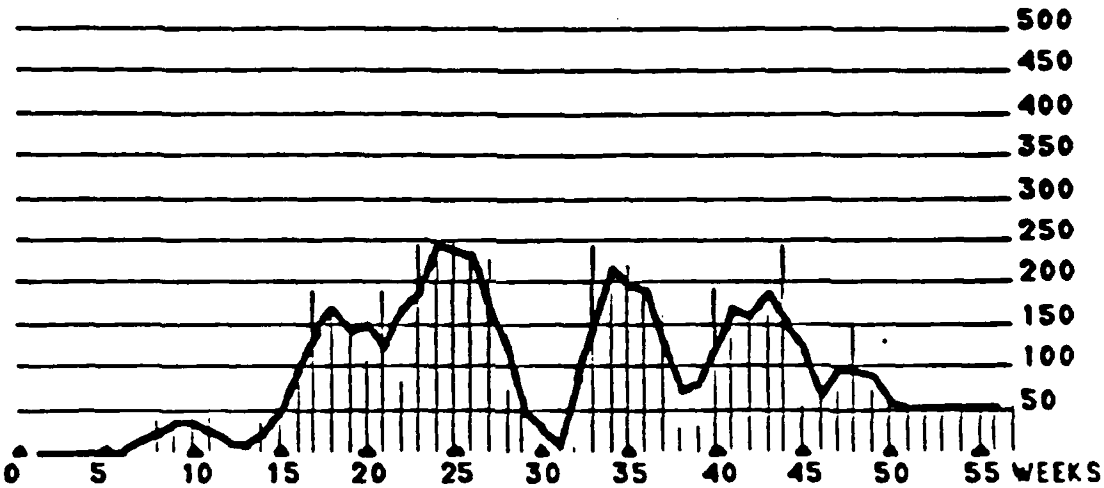
DOOR GUNNERY RANGE



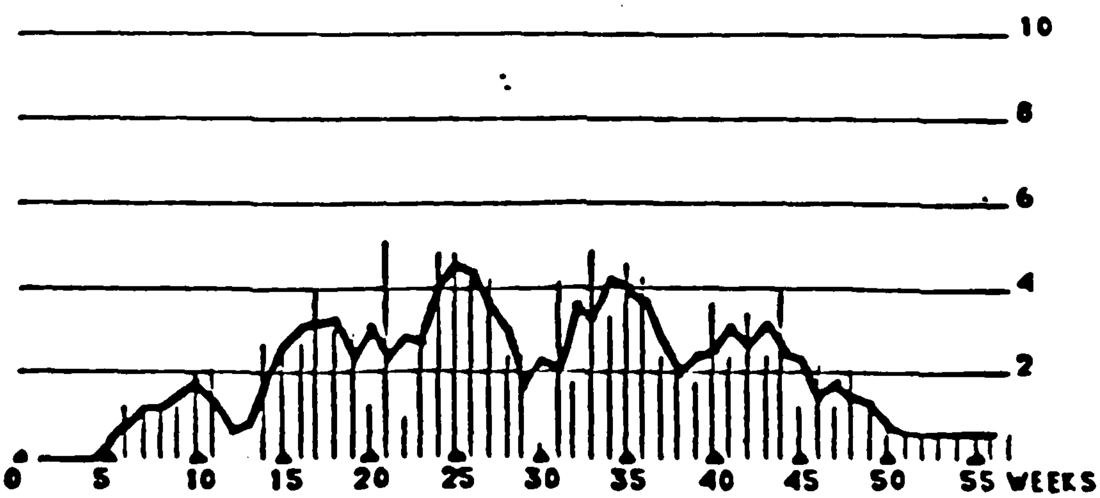
MANEUVER AREA



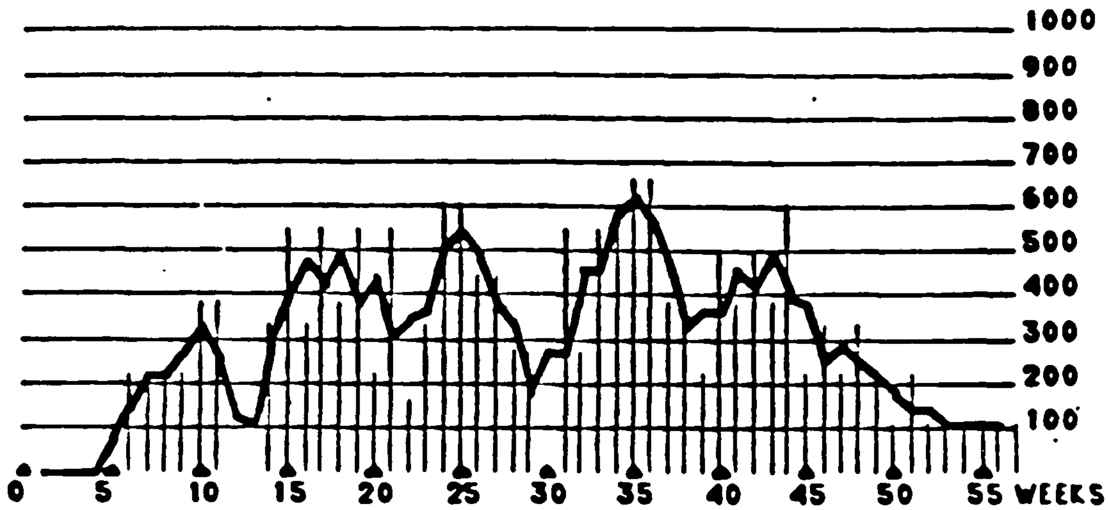
OPFOR



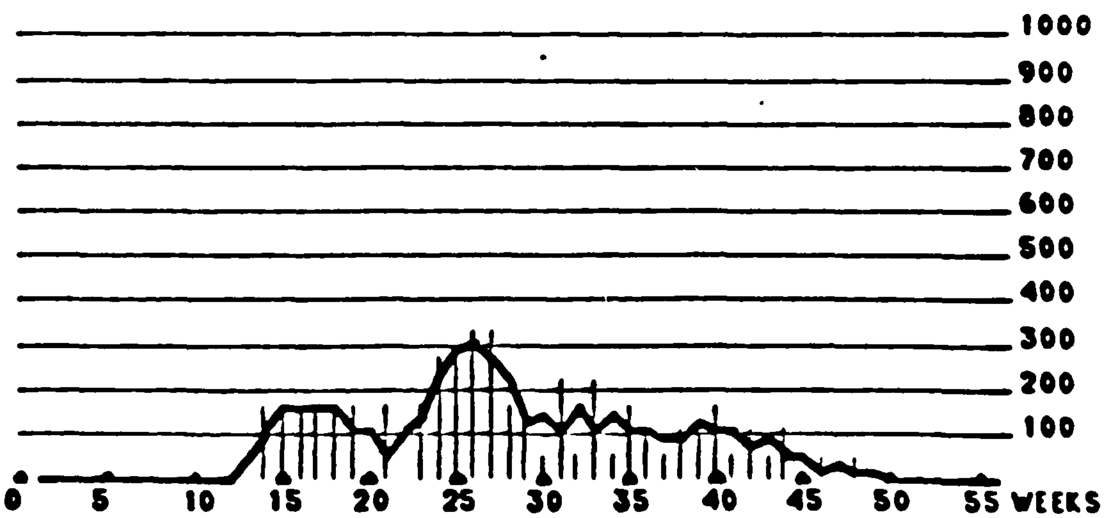
TEAM TRAINER



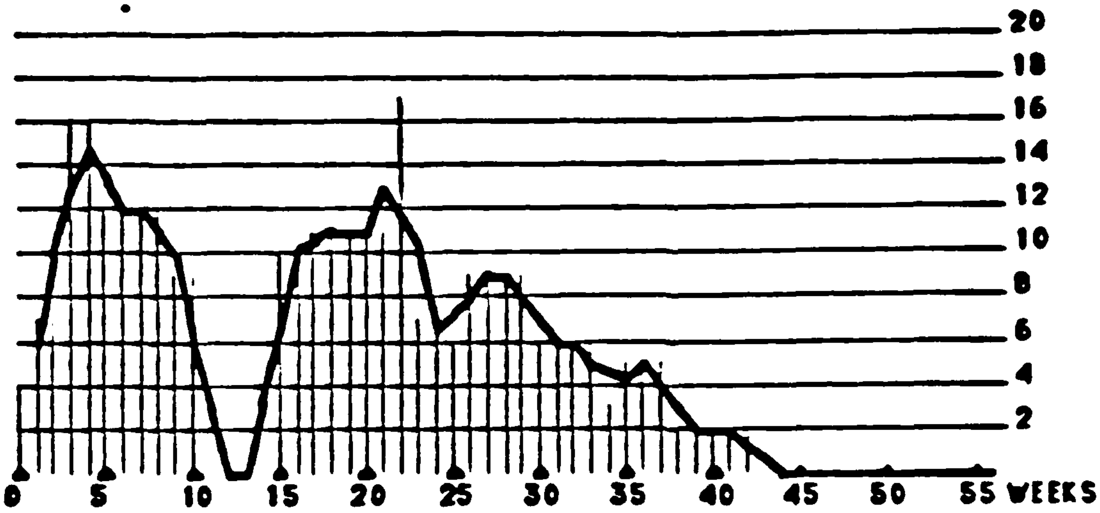
SCAT FLYING HOURS



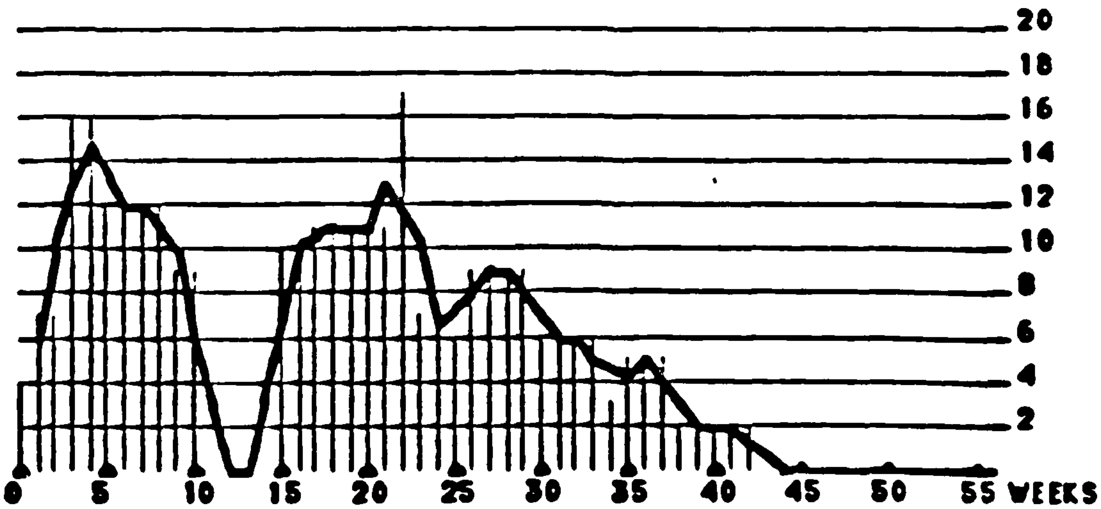
UTILITY FLYING HOURS



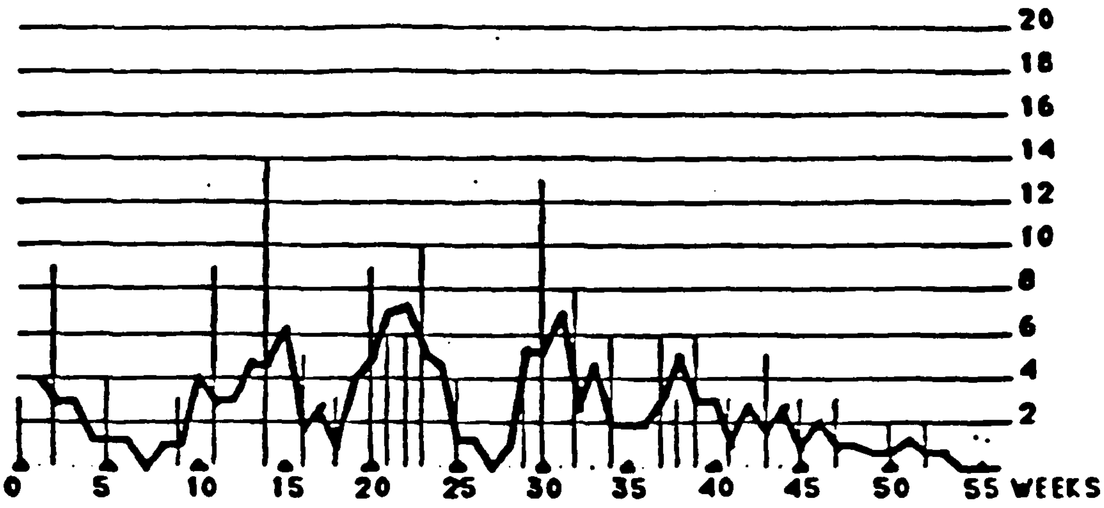
EXTERNAL AIRCRAFT



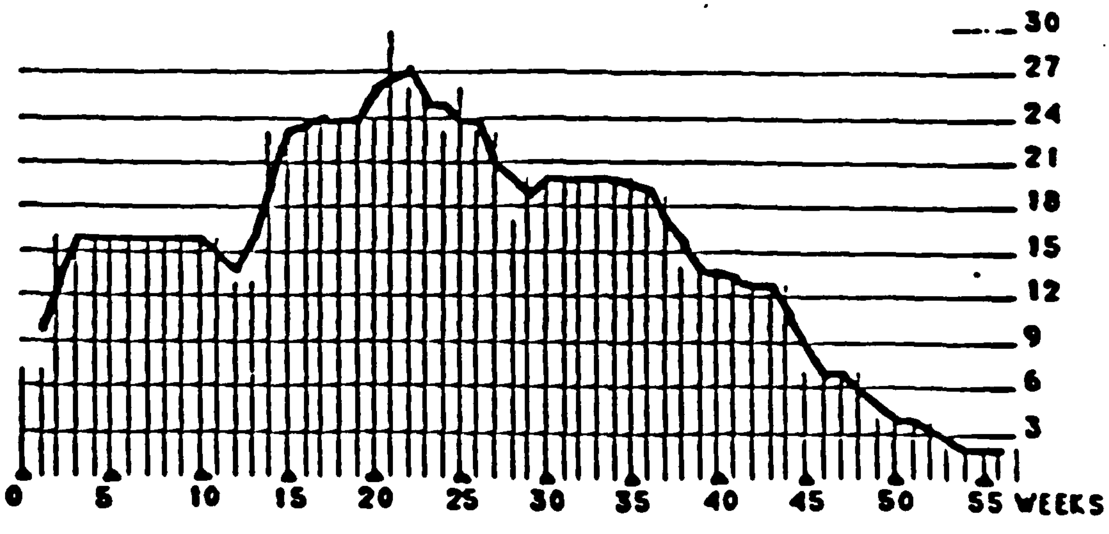
EXTERNAL TOE EQUIPMENT



ADMINISTRATIVE

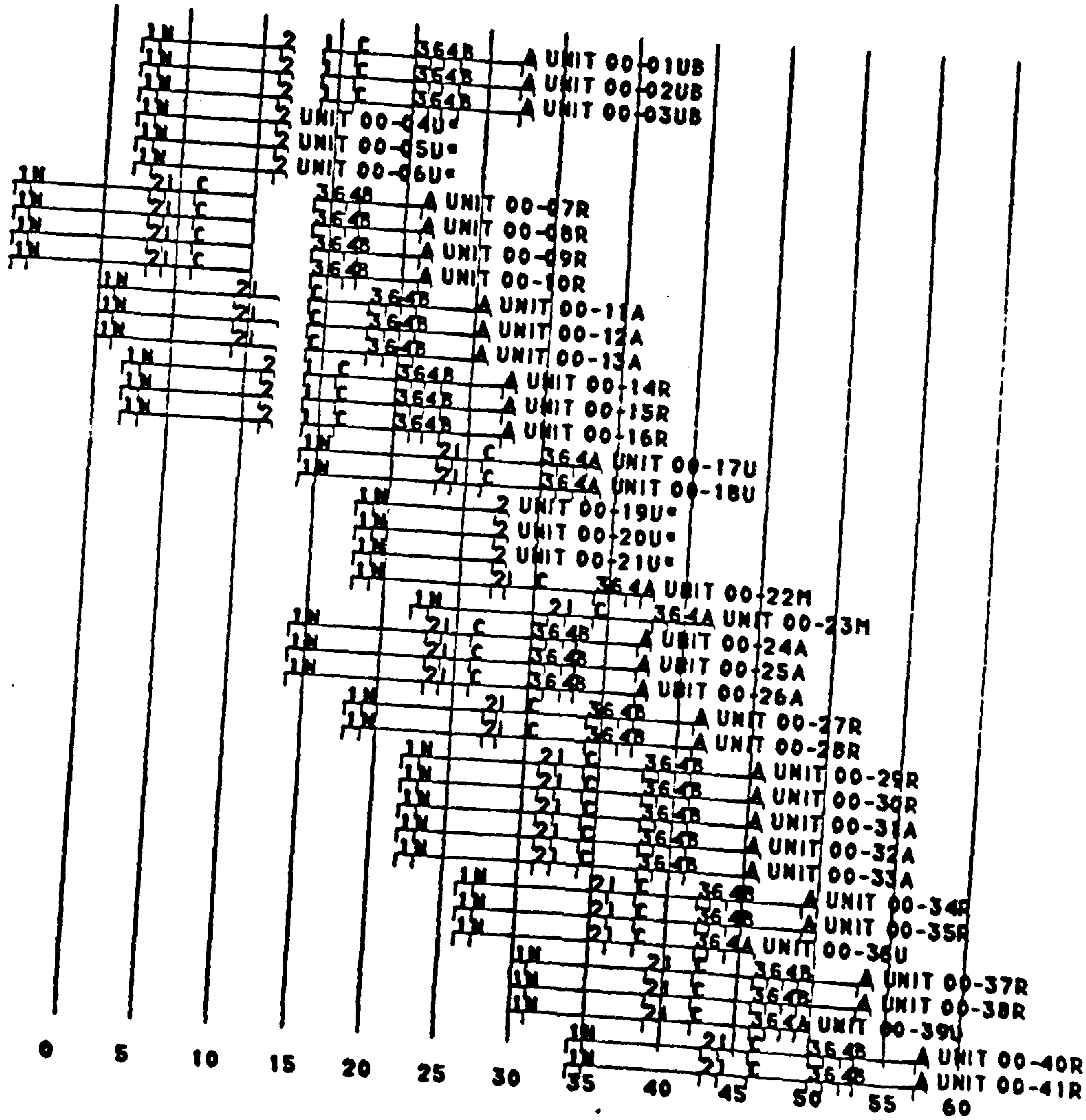


DOWNTIME



BASELINE CASE
DECONFLICTED

TRAINING SCHEDULE



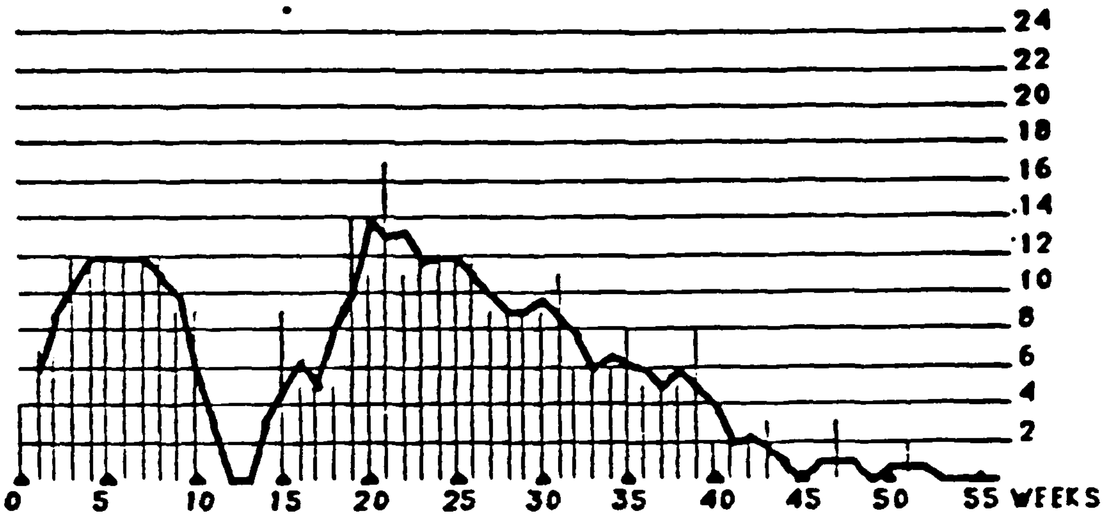
UNIT TRAINING TIMES

Unit	Week Start	Week End	Duration In Weeks
UNIT 00-01UB	2	28	26
UNIT 00-02UB	2	28	26
UNIT 00-03UB	2	28	26
UNIT 00-04U*	2	12	10
UNIT 00-05U*	2	12	10
UNIT 00-06U*	2	12	10
UNIT 00-07R	-6	22	28
UNIT 00-08R	-6	22	28
UNIT 00-09R	-6	22	28
UNIT 00-10R	-6	22	28
UNIT 00-11A	0	26	26
UNIT 00-12A	0	26	26
UNIT 00-13A	0	26	26
UNIT 00-14R	2	28	26
UNIT 00-15R	2	28	26
UNIT 00-16R	2	28	26
UNIT 00-17U	14	34	20
UNIT 00-18U	14	34	20
UNIT 00-19U*	18	28	10
UNIT 00-20U*	18	28	10
UNIT 00-21U*	18	28	10
UNIT 00-22H	18	38	20
UNIT 00-23H	22	42	20
UNIT 00-24A	14	38	24
UNIT 00-25A	14	38	24
UNIT 00-26A	14	38	24
UNIT 00-27R	18	42	24
UNIT 00-28R	18	42	24
UNIT 00-29R	22	46	24
UNIT 00-30R	22	46	24
UNIT 00-31A	22	46	24
UNIT 00-32A	22	46	24
UNIT 00-33A	22	46	24
UNIT 00-34R	26	50	24
UNIT 00-35R	26	50	24
UNIT 00-36U	26	46	20
UNIT 00-37R	30	54	24
UNIT 00-38R	30	54	24
UNIT 00-39U	30	50	20
UNIT 00-40R	34	58	24
UNIT 00-41R	34	58	24

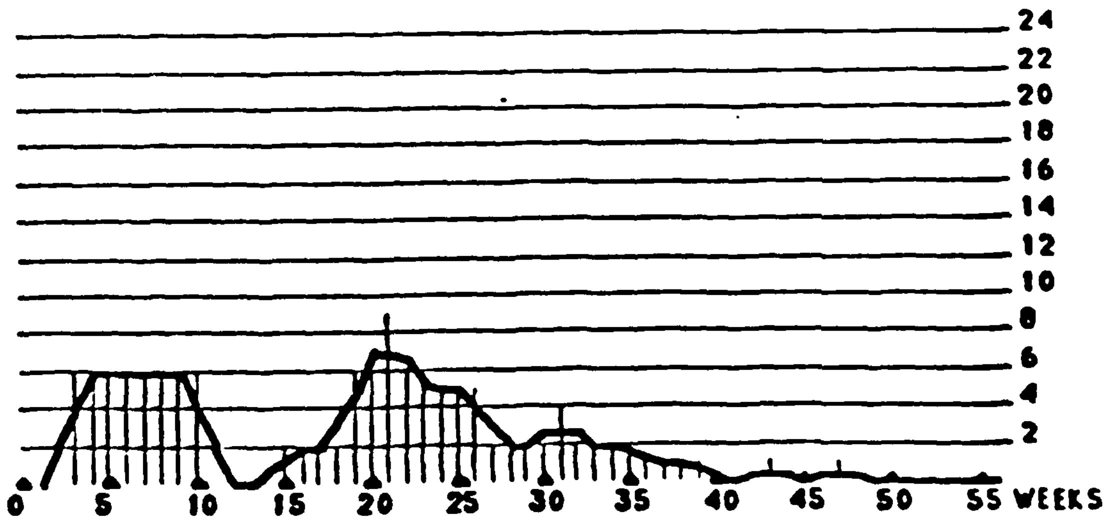
Average Unit Readiness Downtime is 22.2 weeks
Average time to new equipment readiness is 35.4 weeks

CRITICAL RESOURCE DISTRIBUTIONS
FOR BASELINE CASE (DECONFLICTED)

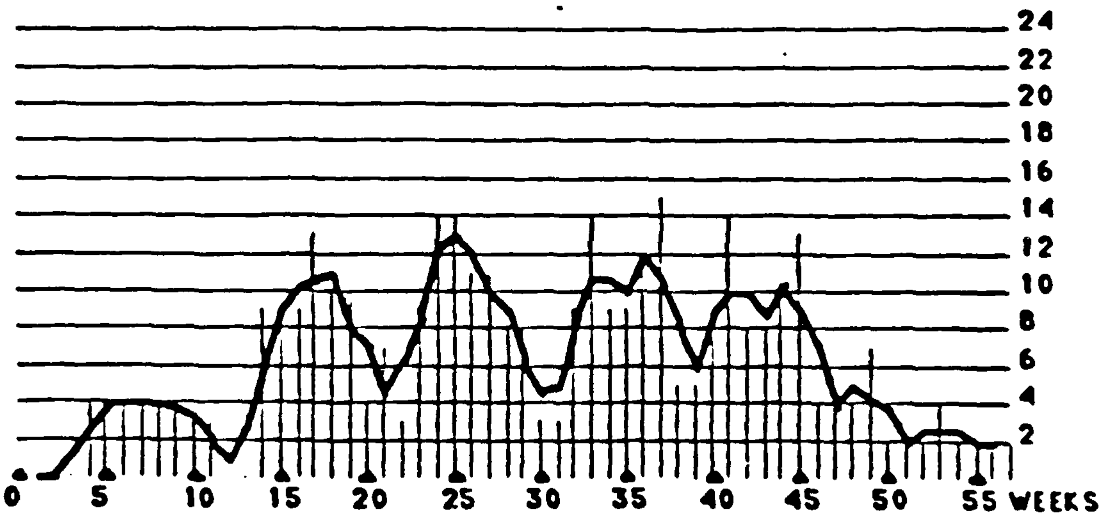
AERIAL GUNNERY RANGE



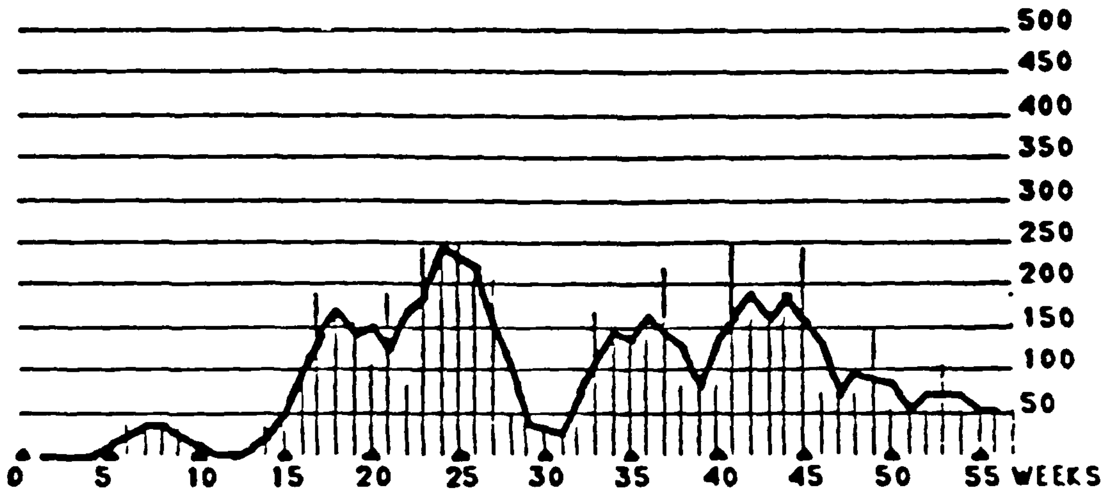
DOOR GUNNERY RANGE



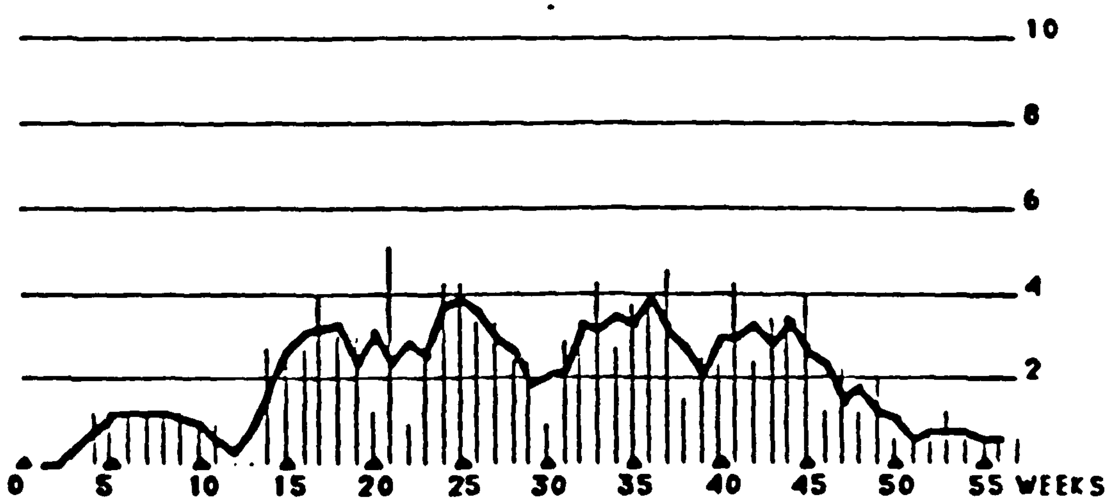
MANEUVER AREA



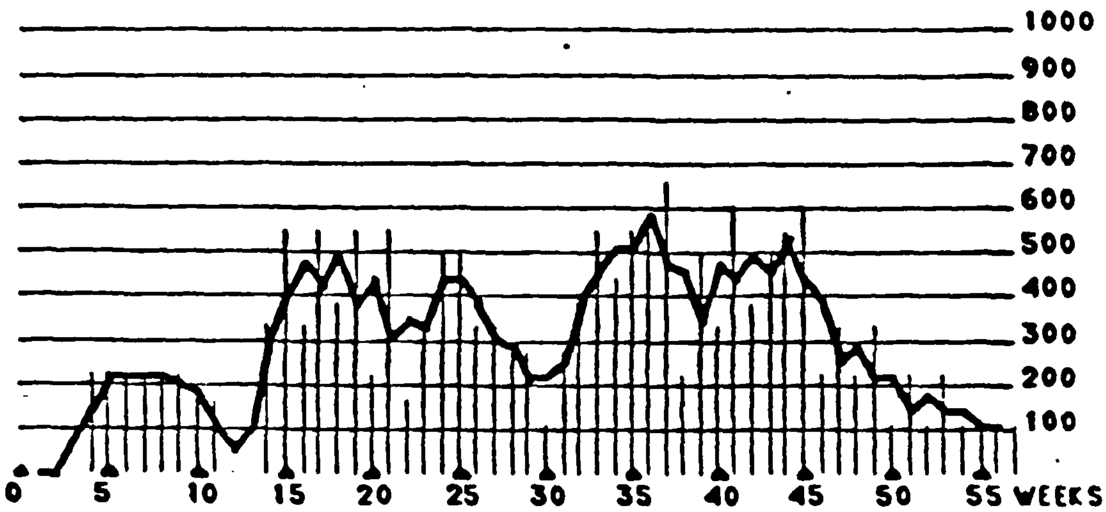
OPFOR



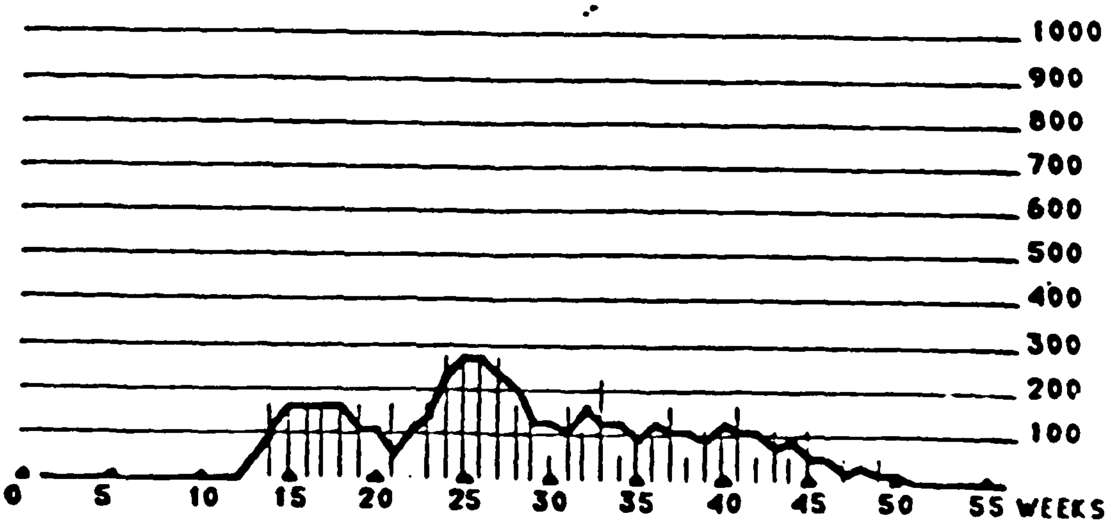
TEAM TRAINER



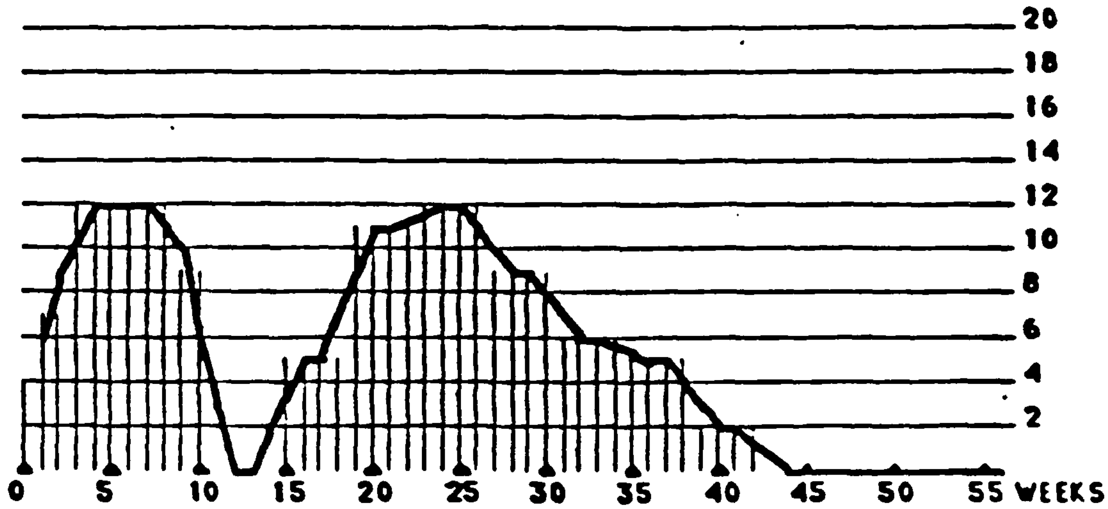
SCAT FLYING HOURS



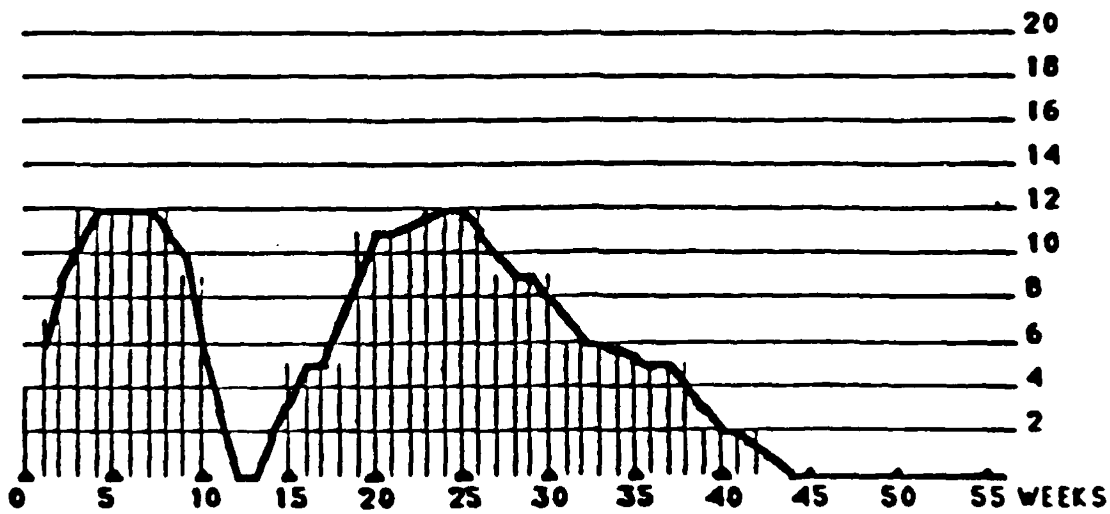
UTILITY FLYING HOURS



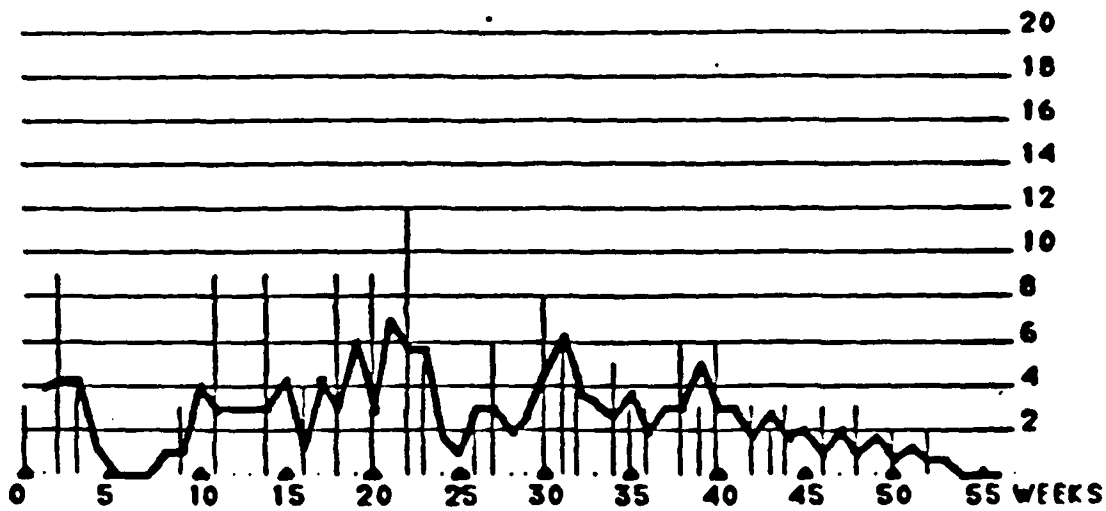
EXTERNAL AIRCRAFT



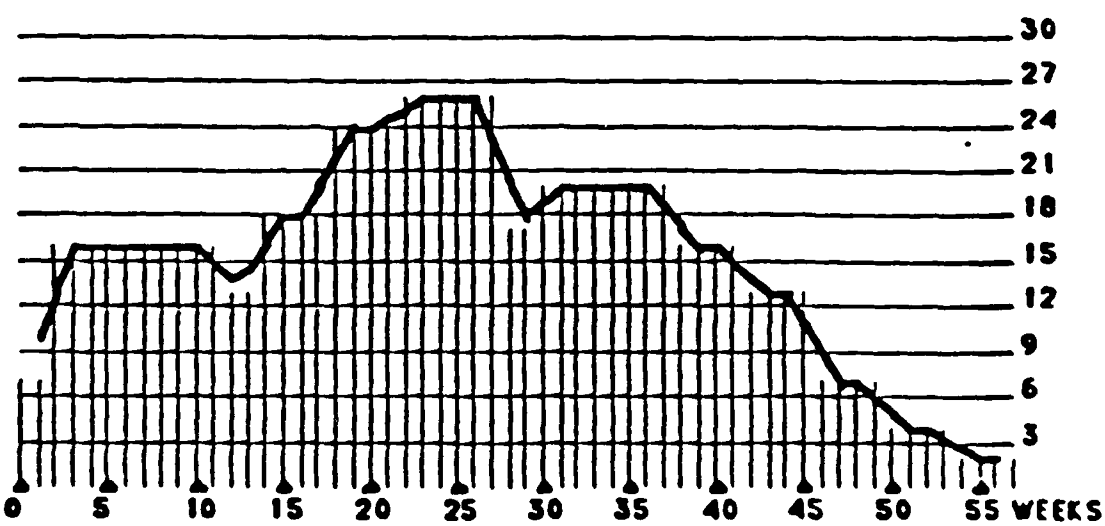
EXTERNAL TOE EQUIPMENT



ADMINISTRATIVE

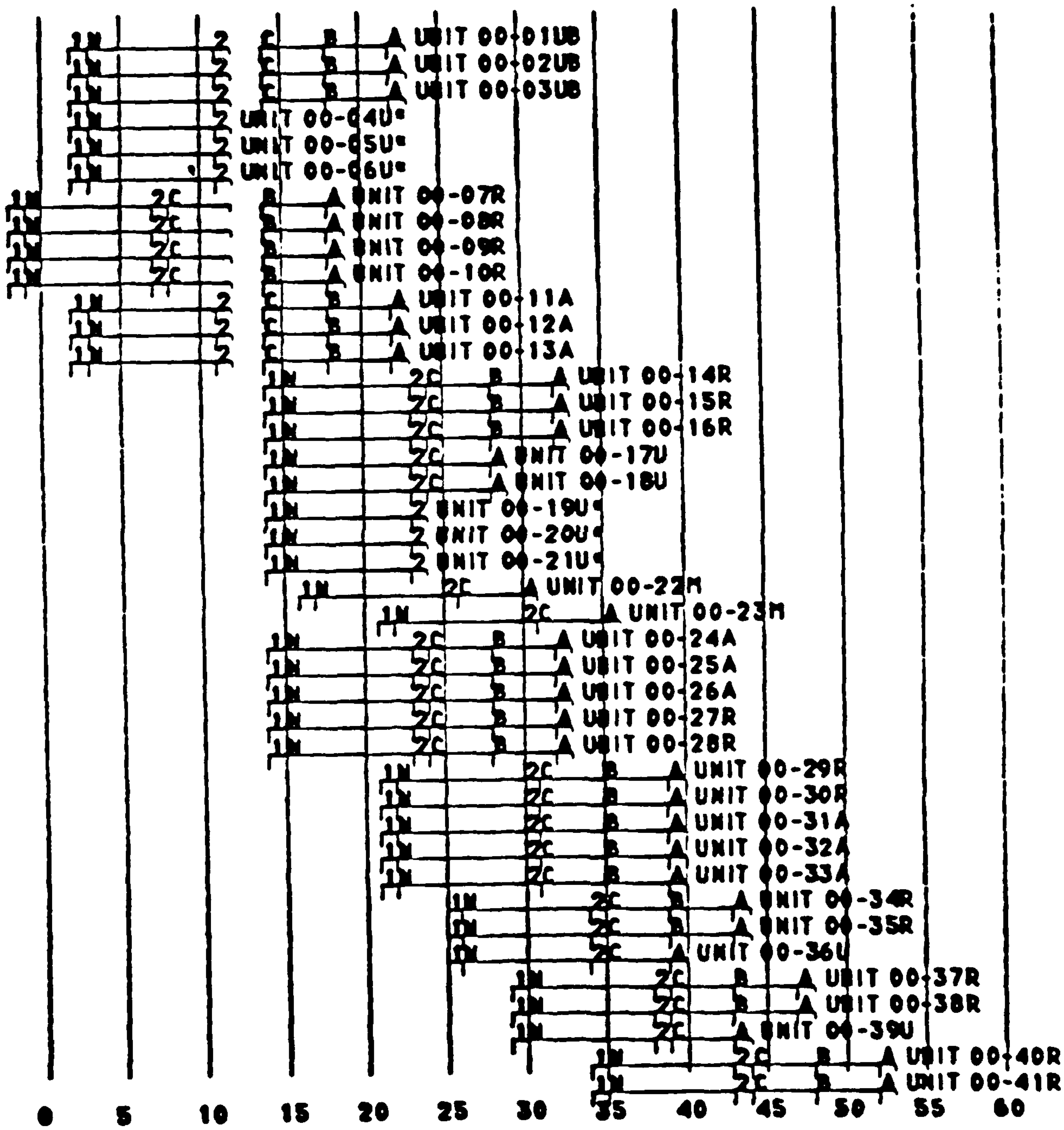


DOWNTIME



TRAINING ALTERNATIVE 1
PRIOR TO DECONFLICTION ANALYSES

TRAINING SCHEDULE



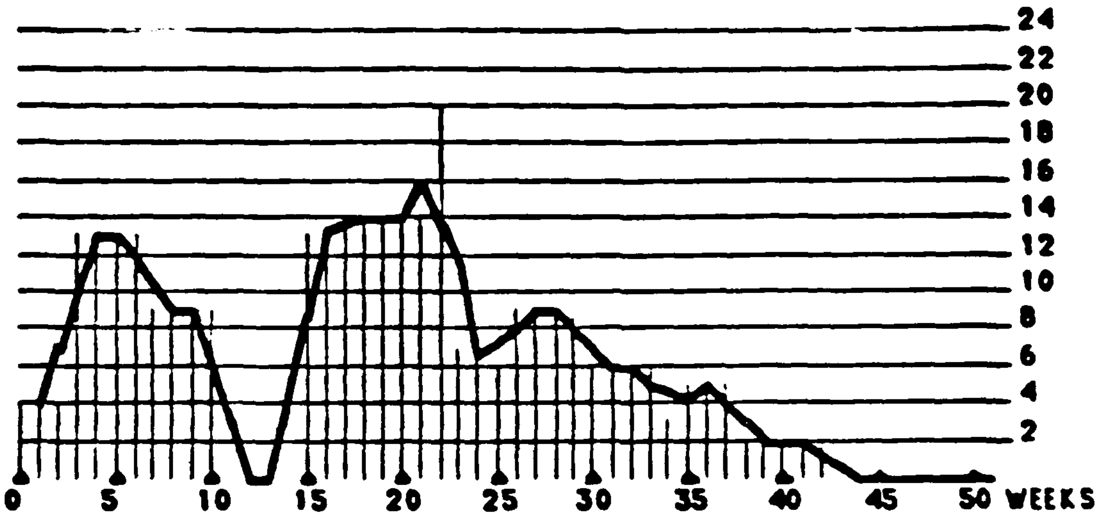
UNIT TRAINING TIMES

Unit	Week Start	Week End	Duration In Weeks
UNIT 00-01UB	2	23	21
UNIT 00-02UB	2	23	21
UNIT 00-03UB	2	23	21
UNIT 00-04U*	2	12	10
UNIT 00-05U*	2	12	10
UNIT 00-06U*	2	12	10
UNIT 00-07R	-2	19	21
UNIT 00-08R	-2	19	21
UNIT 00-09R	-2	19	21
UNIT 00-10R	-2	19	21
UNIT 00-11A	2	23	21
UNIT 00-12A	2	23	21
UNIT 00-13A	2	23	21
UNIT 00-14R	14	33	19
UNIT 00-15R	14	33	19
UNIT 00-16R	14	33	19
UNIT 00-17U	14	29	15
UNIT 00-18U	14	29	15
UNIT 00-19U*	14	24	10
UNIT 00-20U*	14	24	10
UNIT 00-21U*	14	24	10
UNIT 00-22M	16	31	15
UNIT 00-23M	21	36	15
UNIT 00-24A	14	33	19
UNIT 00-25A	14	33	19
UNIT 00-26A	14	33	19
UNIT 00-27R	14	33	19
UNIT 00-28R	14	33	19
UNIT 00-29R	21	40	19
UNIT 00-30R	21	40	19
UNIT 00-31A	21	40	19
UNIT 00-32A	21	40	19
UNIT 00-33A	21	40	19
UNIT 00-34R	25	44	19
UNIT 00-35R	25	44	19
UNIT 00-36U	25	40	15
UNIT 00-37R	29	48	19
UNIT 00-38R	29	48	19
UNIT 00-39U	29	44	15
UNIT 00-40R	34	53	19
UNIT 00-41R	34	53	19

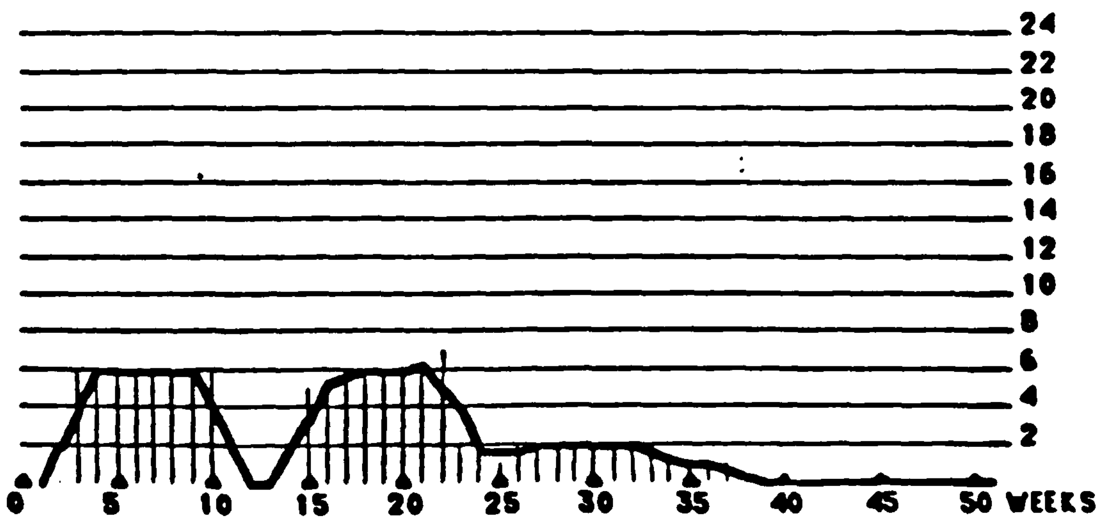
Average Unit Readiness Downtime is 17.6 weeks
Average time to new equipment readiness is 31.3 weeks

CRITICAL RESOURCE DISTRIBUTIONS FOR TRAINING ALTERNATIVE 1

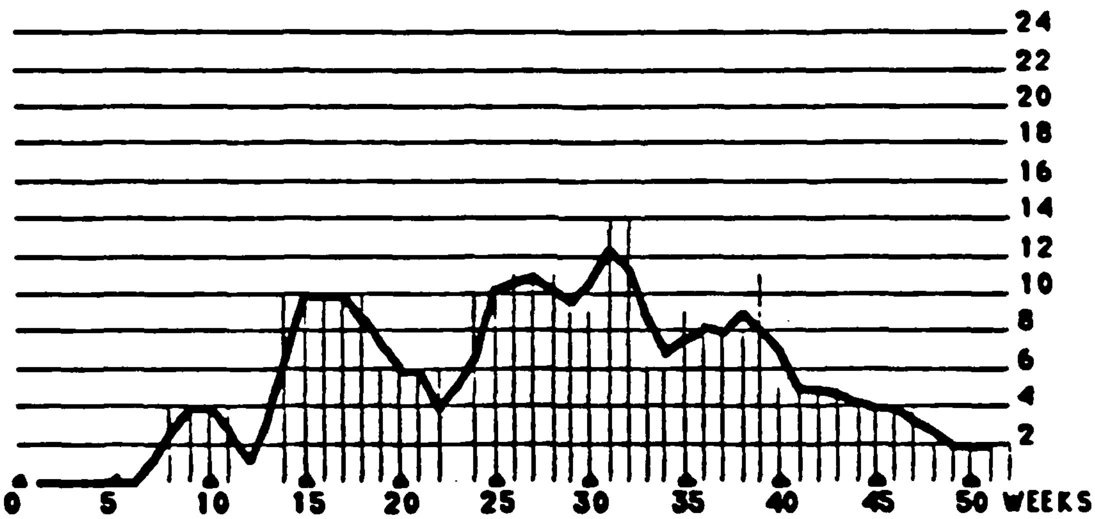
AERIAL GUNNERY RANGE



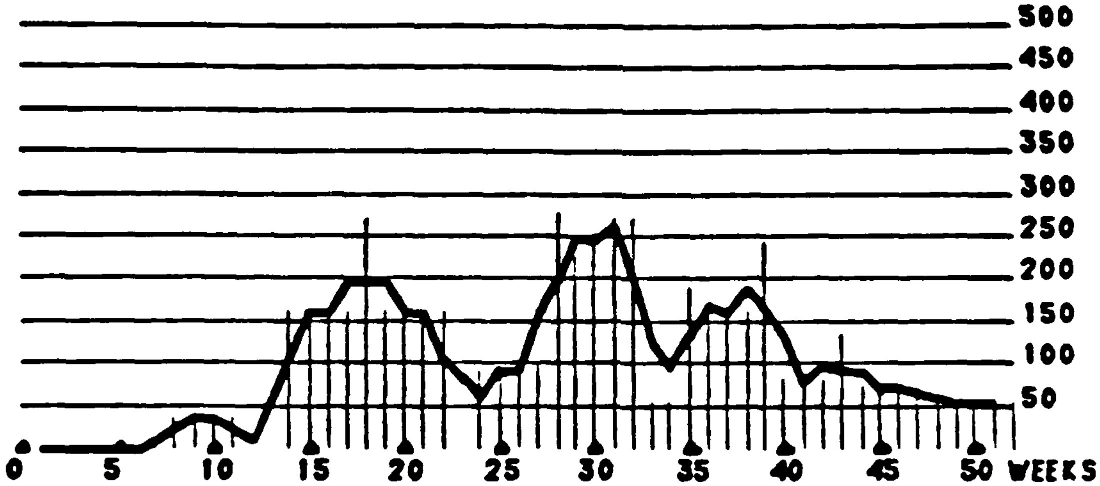
DOOR GUNNERY RANGE



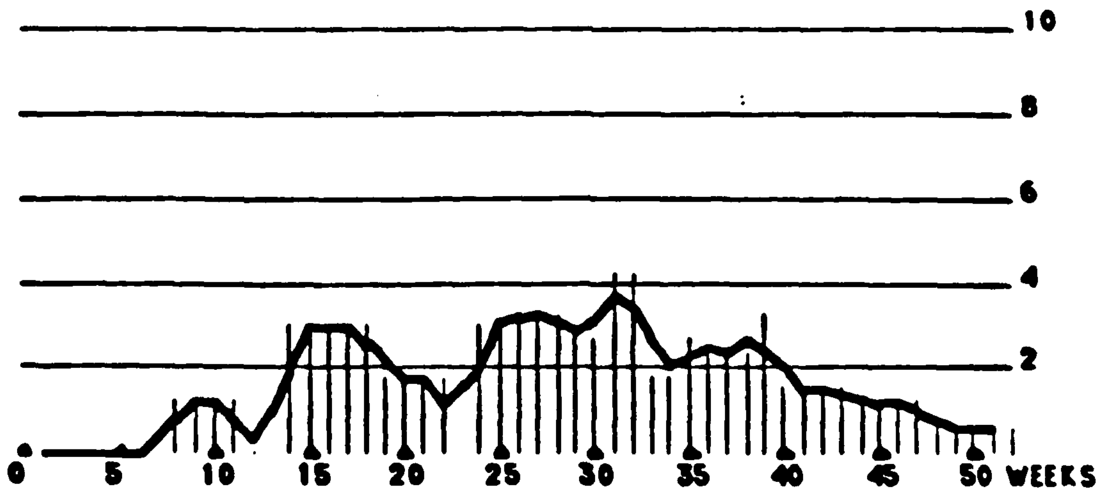
MANEUVER AREA



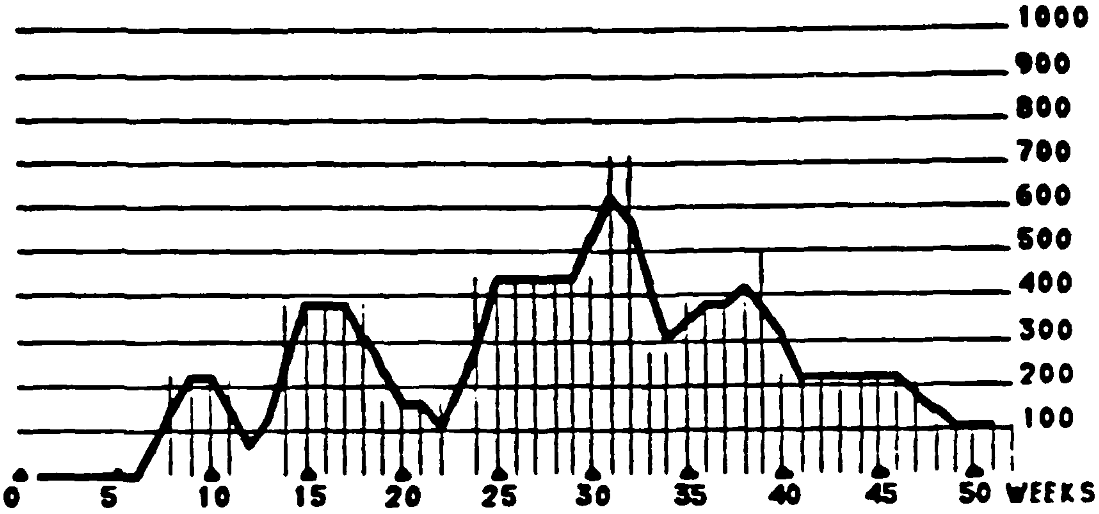
OPFOR



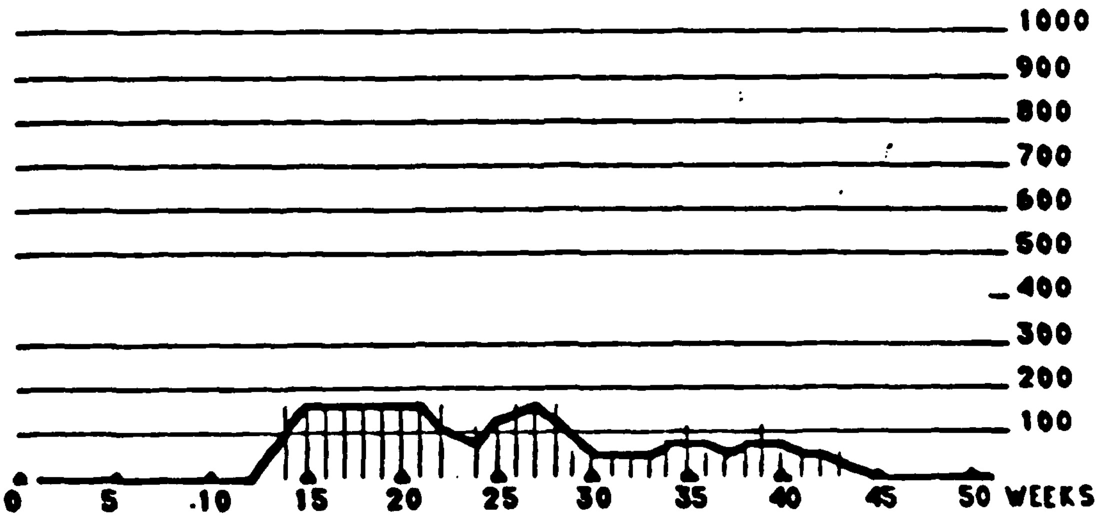
TEAM TRAINER



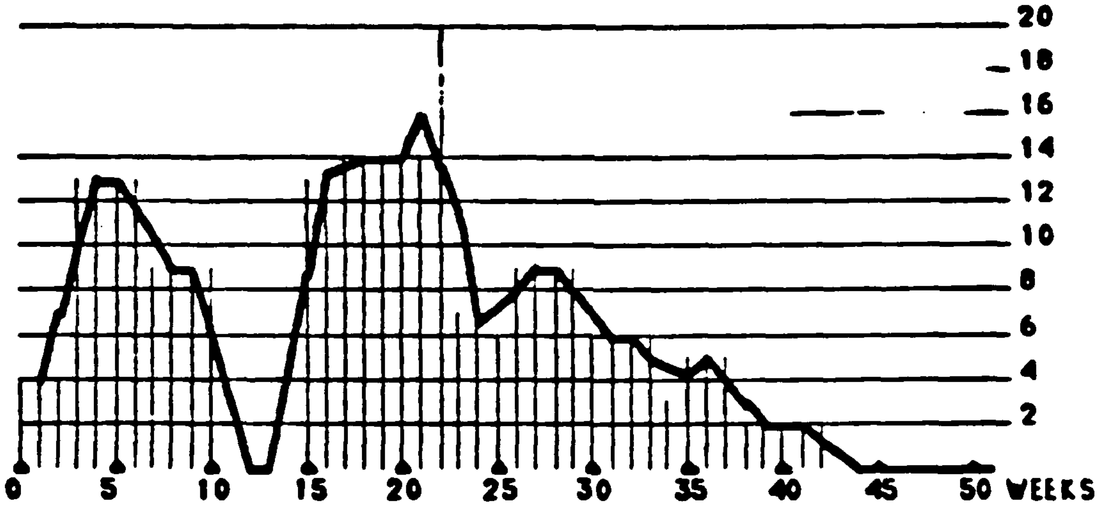
SCAT FLYING HOURS



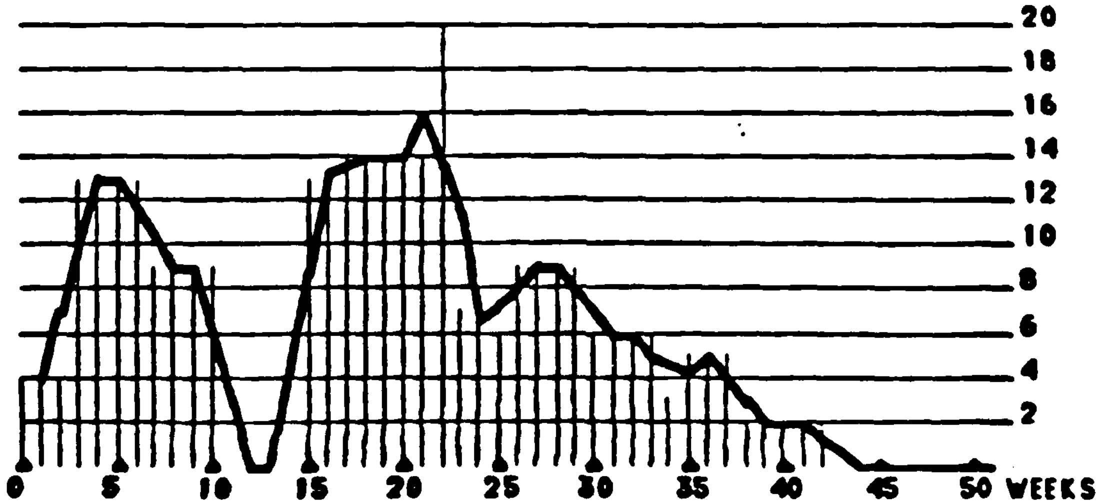
UTILITY FLYING HOURS



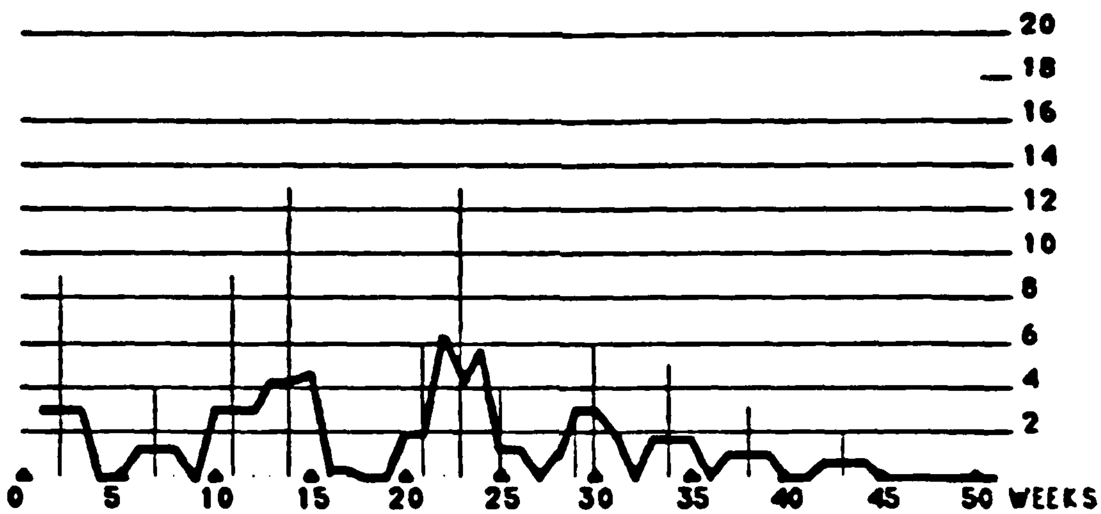
EXTERNAL AIRCRAFT



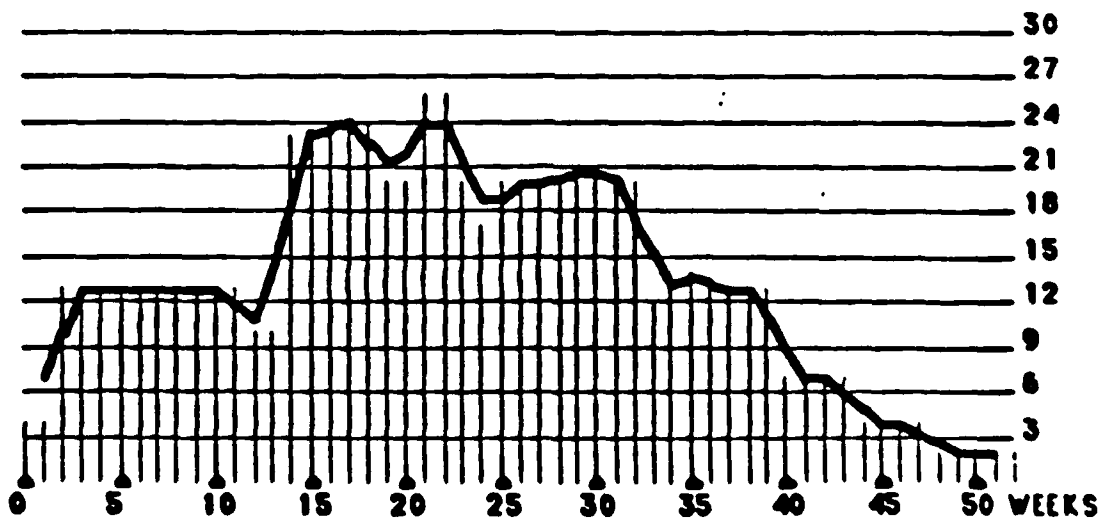
EXTERNAL TOE EQUIPMENT



ADMINISTRATIVE

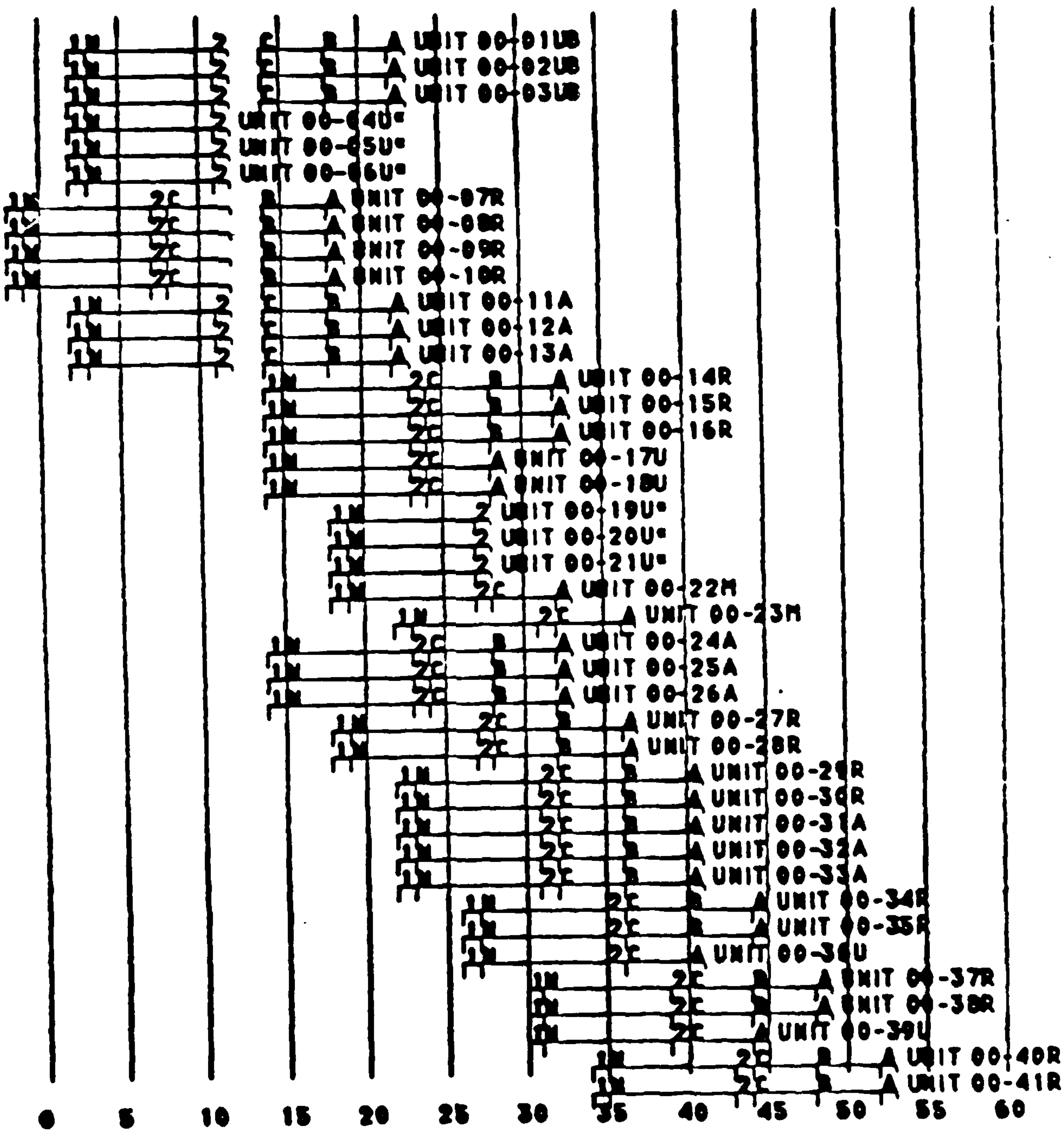


DOWNTIME



TRAINING ALTERNATIVE 1
DECONFLICTED

TRAINING SCHEDULE



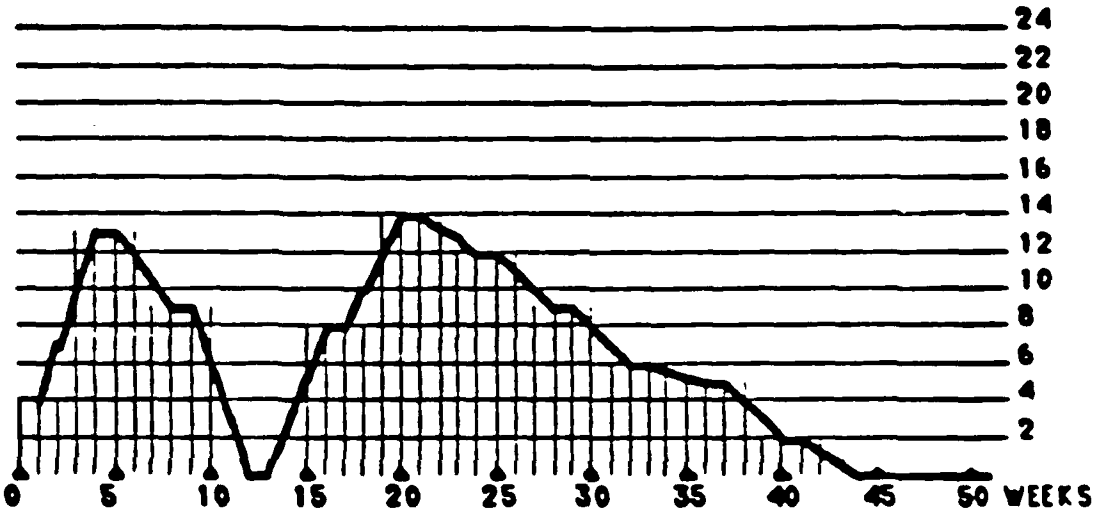
UNIT TRAINING TIMES

Unit	Week Start	Week End	Duration In Weeks
UNIT 00-01UB	2	23	21
UNIT 00-02UB	2	23	21
UNIT 00-03UB	2	23	21
UNIT 00-04U*	2	12	10
UNIT 00-05U*	2	12	10
UNIT 00-06U*	2	12	10
UNIT 00-07R	-2	19	21
UNIT 00-08R	-2	19	21
UNIT 00-09R	-2	19	21
UNIT 00-10R	-2	19	21
UNIT 00-11A	2	23	21
UNIT 00-12A	2	23	21
UNIT 00-13A	2	23	21
UNIT 00-14R	14	33	19
UNIT 00-15R	14	33	19
UNIT 00-16R	14	33	19
UNIT 00-17U	14	29	15
UNIT 00-18U	14	29	15
UNIT 00-19U*	18	28	10
UNIT 00-20U*	18	28	10
UNIT 00-21U*	18	28	10
UNIT 00-22M	18	33	15
UNIT 00-23M	22	37	15
UNIT 00-24A	14	33	19
UNIT 00-25A	14	33	19
UNIT 00-26A	14	33	19
UNIT 00-27R	18	37	19
UNIT 00-28R	18	37	19
UNIT 00-29R	22	41	19
UNIT 00-30R	22	41	19
UNIT 00-31A	22	41	19
UNIT 00-32A	22	41	19
UNIT 00-33A	22	41	19
UNIT 00-34R	26	45	19
UNIT 00-35R	26	45	19
UNIT 00-36U	26	41	15
UNIT 00-37R	30	49	19
UNIT 00-38R	30	49	19
UNIT 00-39U	30	45	15
UNIT 00-40R	34	53	19
UNIT 00-41R	34	53	19

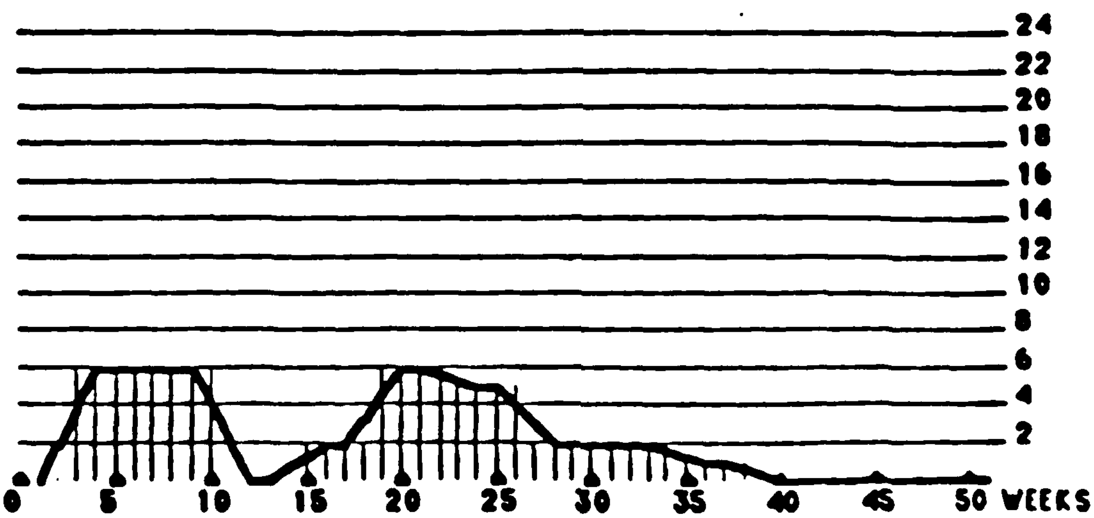
Average Unit Readiness Downtime is 17.6 weeks
Average time to new equipment readiness is 32.2 weeks

CRITICAL RESOURCE DISTRIBUTIONS
FOR TRAINING ALTERNATIVE 1
(DECONFLICTED)

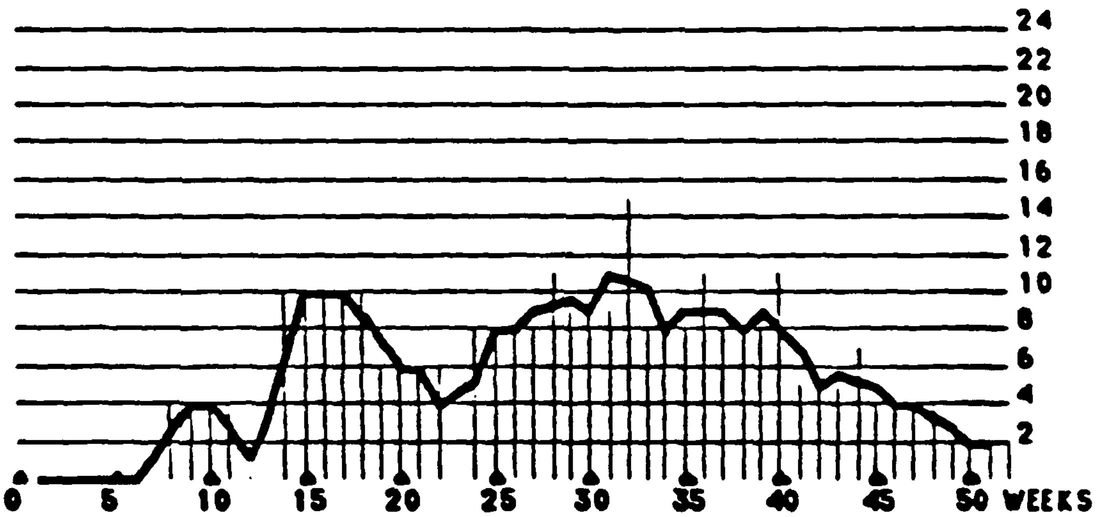
AERIAL GUNNERY RANGE



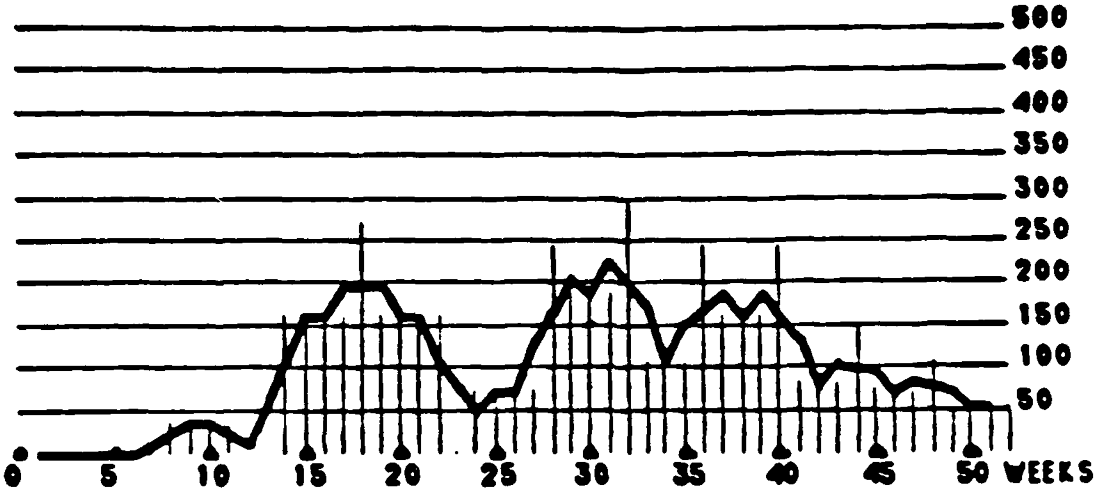
DOOR GUNNERY RANGE



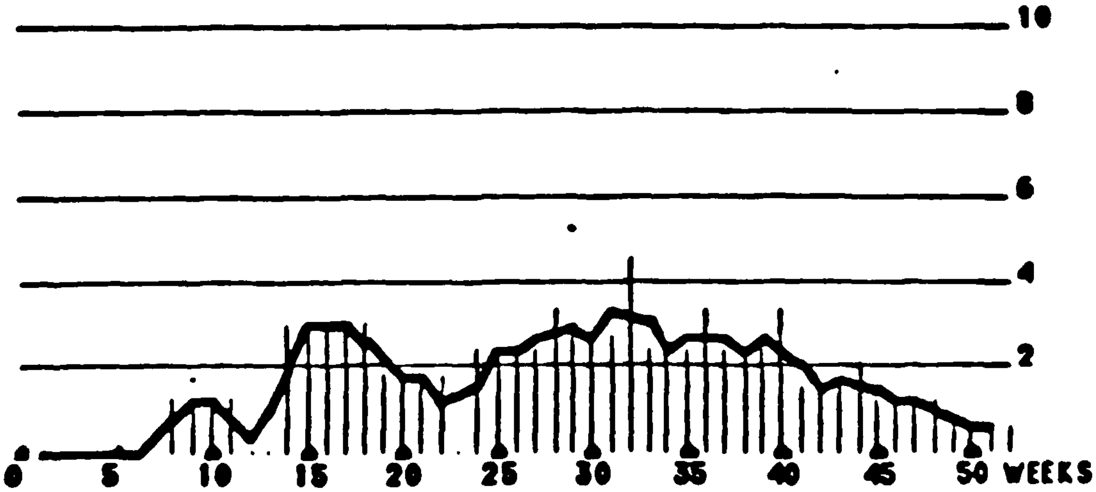
MANEUVER AREA



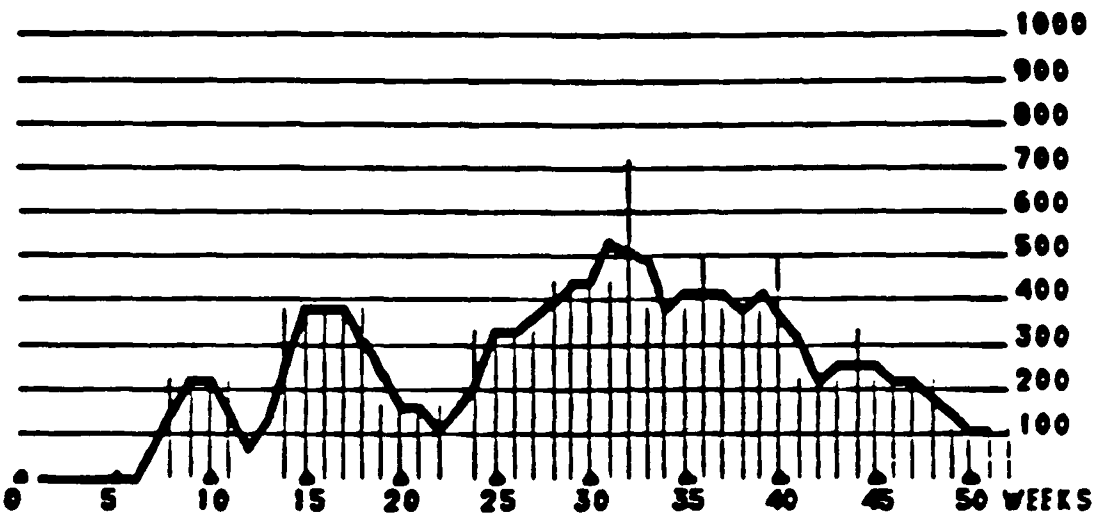
OPFOR



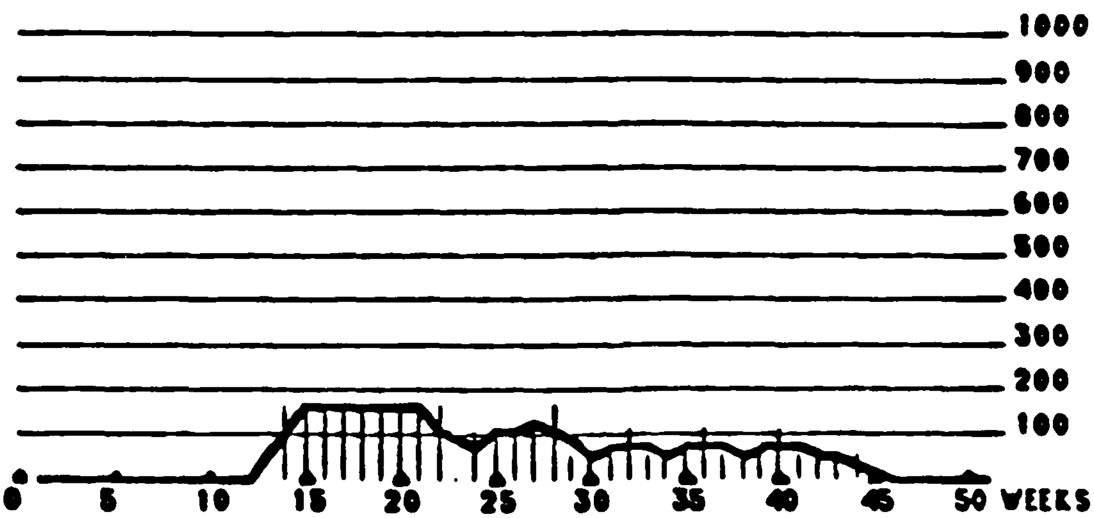
TEAM TRAINER



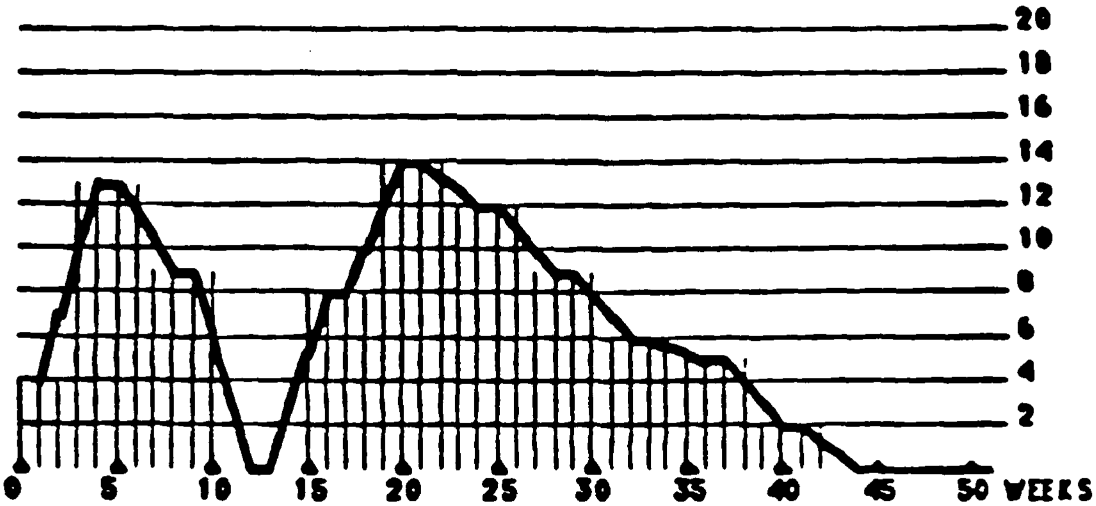
SCAT FLYING HOURS



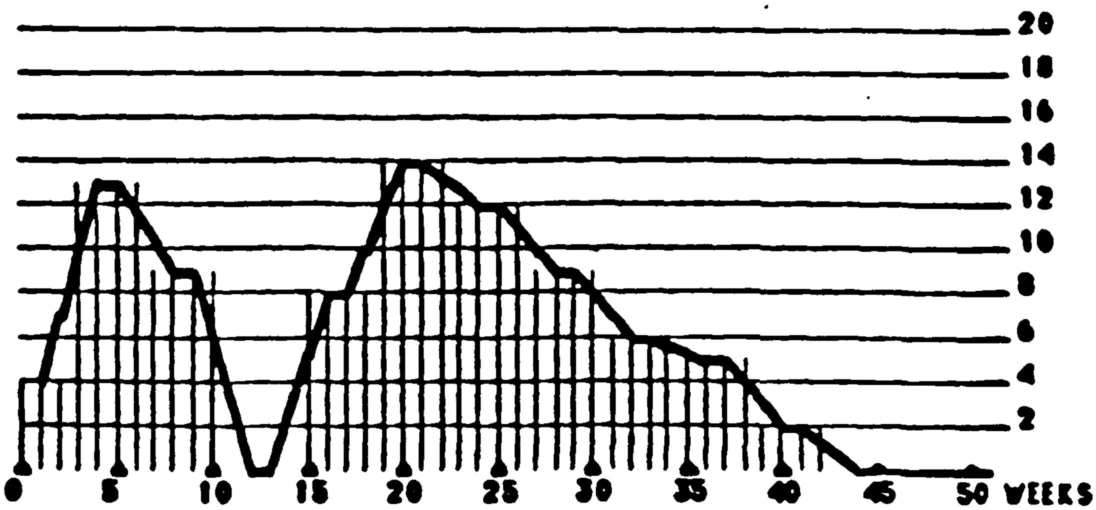
UTILITY FLYING HOURS



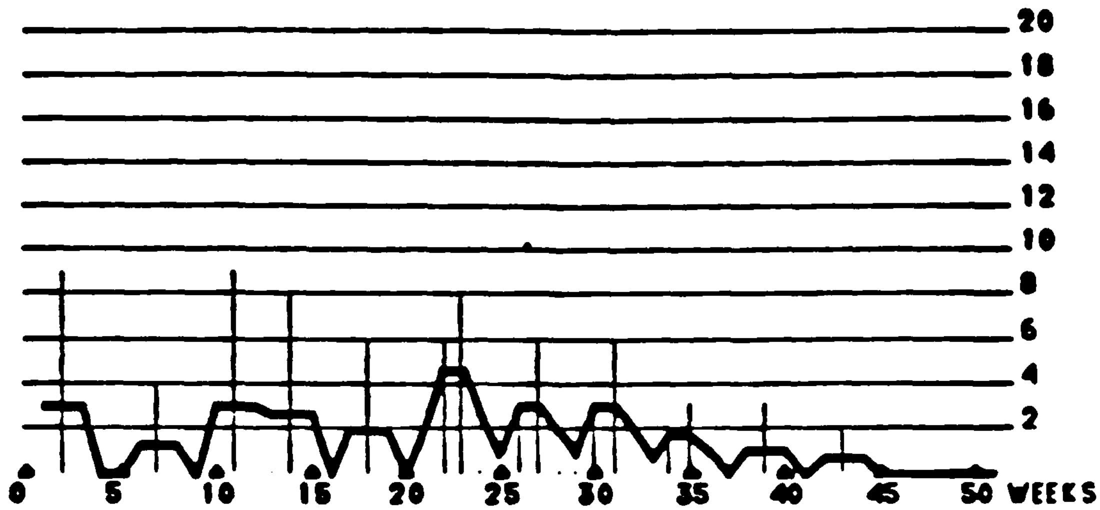
EXTERNAL AIRCRAFT



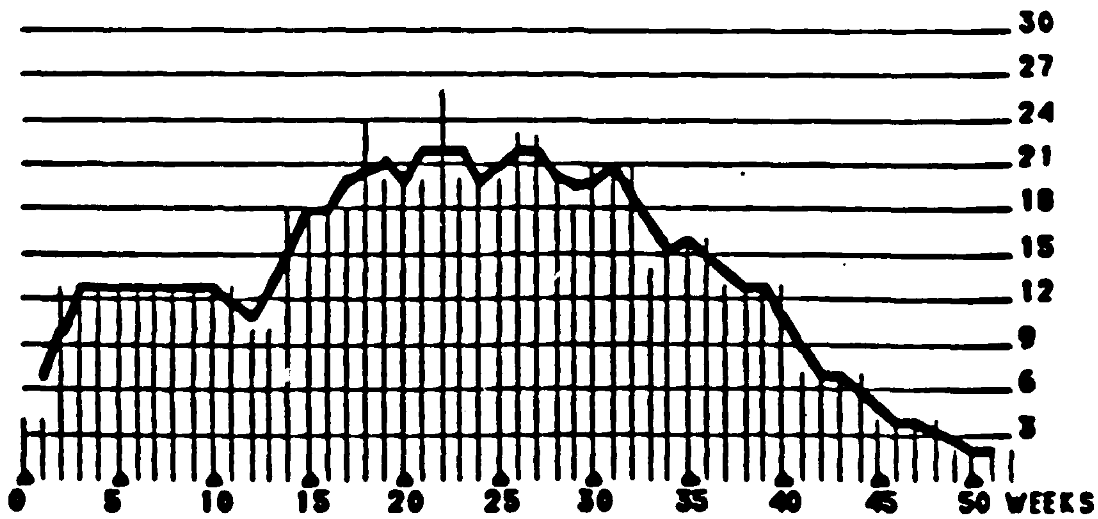
EXTERNAL TOE EQUIPMENT



ADMINISTRATIVE

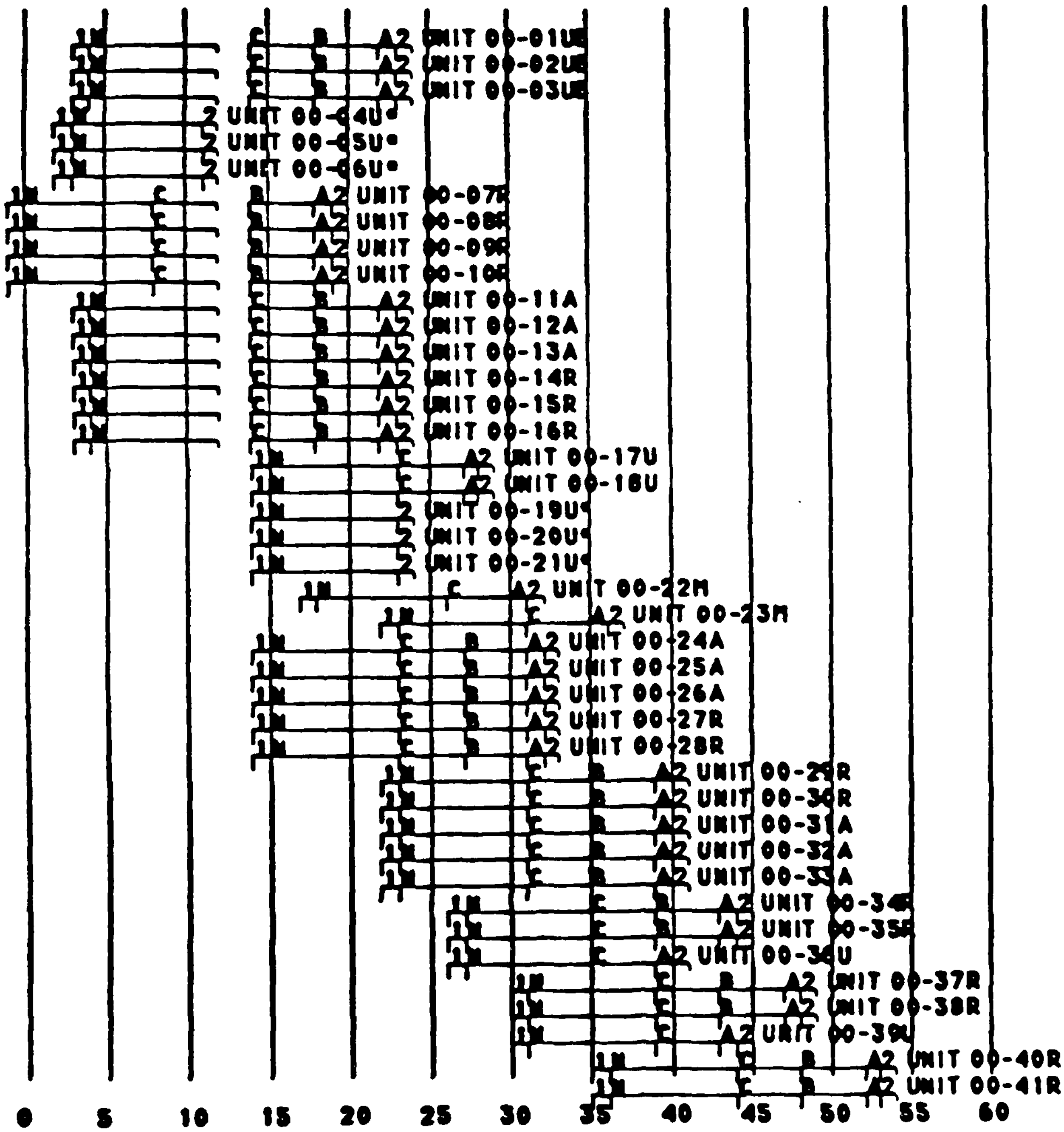


DOWNTIME



TRAINING ALTERNATIVE 2
PRIOR TO DECONFLICTION ANALYSES

TRAINING SCHEDULE



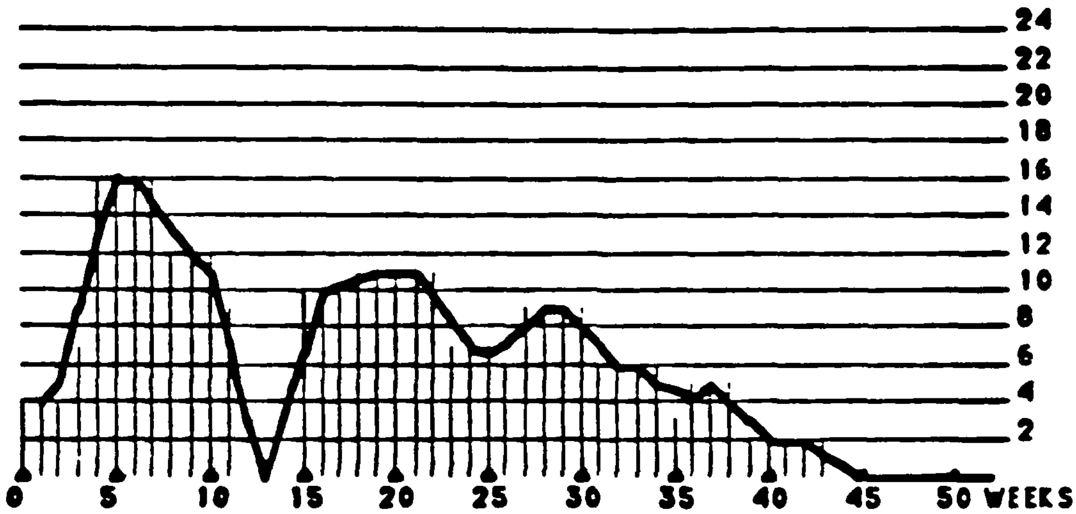
UNIT TRAINING TIMES

Unit	Week Start	Week End	Duration In Weeks
UNIT 00-01UB	3	24	21
UNIT 00-02UB	3	24	21
UNIT 00-03UB	3	24	21
UNIT 00-04U*	2	12	10
UNIT 00-05U*	2	12	10
UNIT 00-06U*	2	12	10
UNIT 00-07R	-1	20	21
UNIT 00-08R	-1	20	21
UNIT 00-09R	-1	20	21
UNIT 00-10R	-1	20	21
UNIT 00-11A	3	24	21
UNIT 00-12A	3	24	21
UNIT 00-13A	3	24	21
UNIT 00-14R	3	24	21
UNIT 00-15R	3	24	21
UNIT 00-16R	3	24	21
UNIT 00-17U	14	29	15
UNIT 00-18U	14	29	15
UNIT 00-19U*	14	24	10
UNIT 00-20U*	14	24	10
UNIT 00-21U*	14	24	10
UNIT 00-22M	17	32	15
UNIT 00-23M	22	37	15
UNIT 00-24A	14	33	19
UNIT 00-25A	14	33	19
UNIT 00-26A	14	33	19
UNIT 00-27R	14	33	19
UNIT 00-28R	14	33	19
UNIT 00-29R	22	41	19
UNIT 00-30R	22	41	19
UNIT 00-31A	22	41	19
UNIT 00-32A	22	41	19
UNIT 00-33A	22	41	19
UNIT 00-34R	26	45	19
UNIT 00-35R	26	45	19
UNIT 00-36U	26	41	15
UNIT 00-37R	30	49	19
UNIT 00-38R	30	49	19
UNIT 00-39U	30	45	15
UNIT 00-40R	35	54	19
UNIT 00-41R	35	54	19

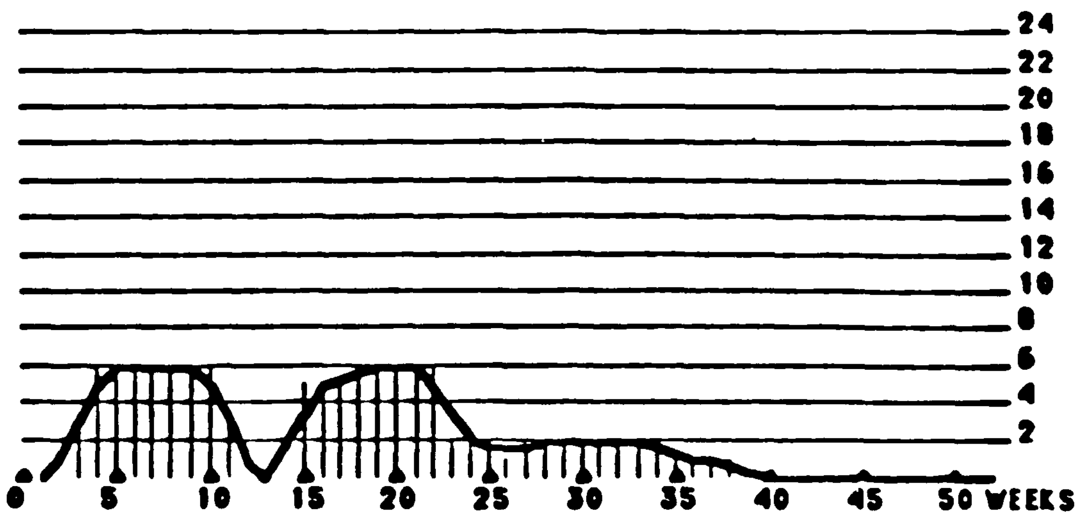
Average Unit Readiness Downtime is 17.7 weeks
Average time to new equipment readiness is 31.3 weeks

CRITICAL RESOURCE
DISTRIBUTION FOR
TRAINING ALTERNATIVE 2

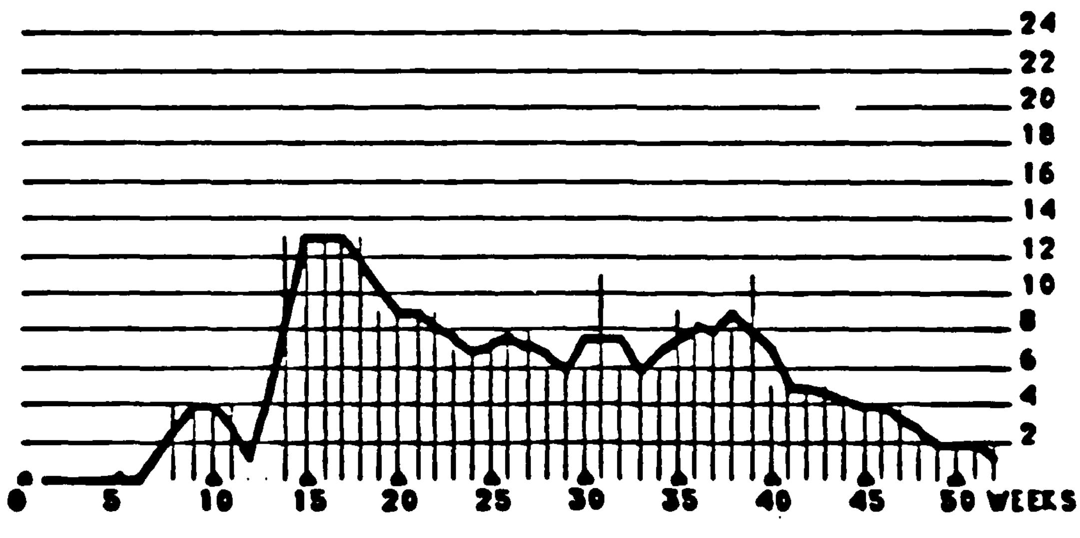
AERIAL GUNNERY RANGE



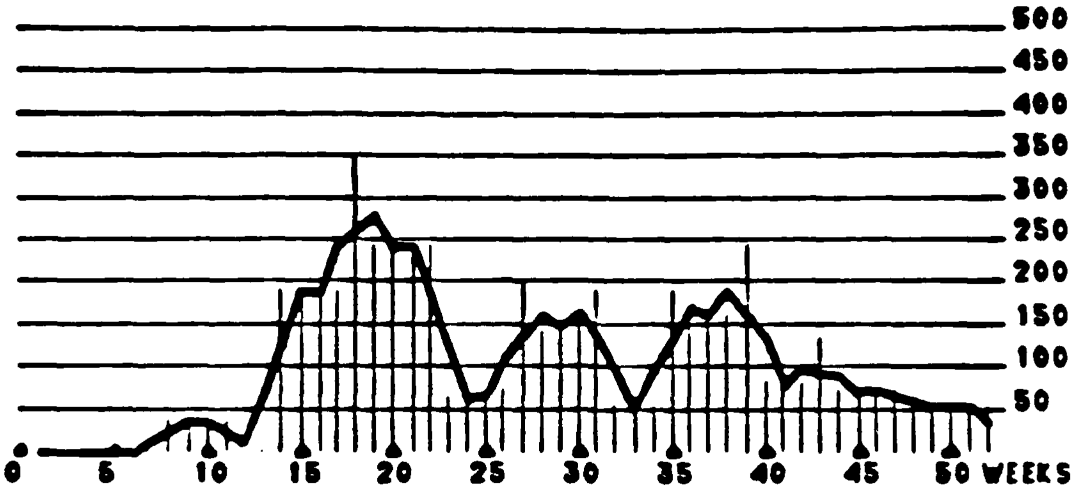
DOOR GUNNERY RANGE



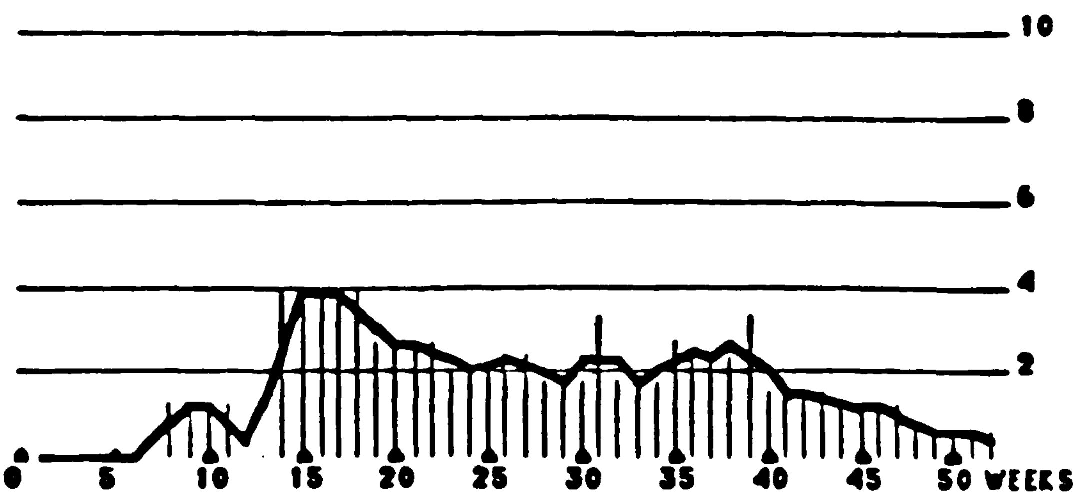
MANEUVER AREA



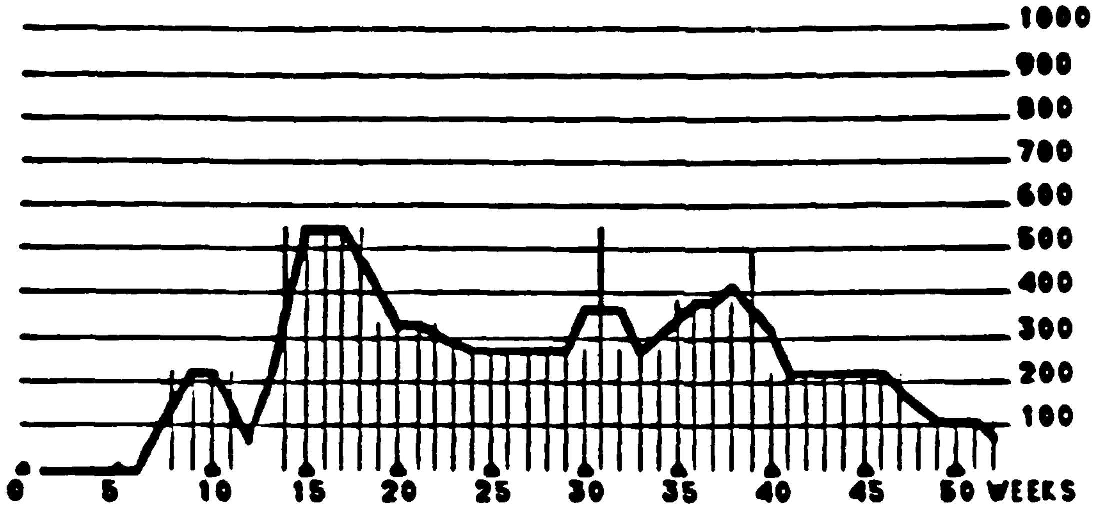
OPFOR



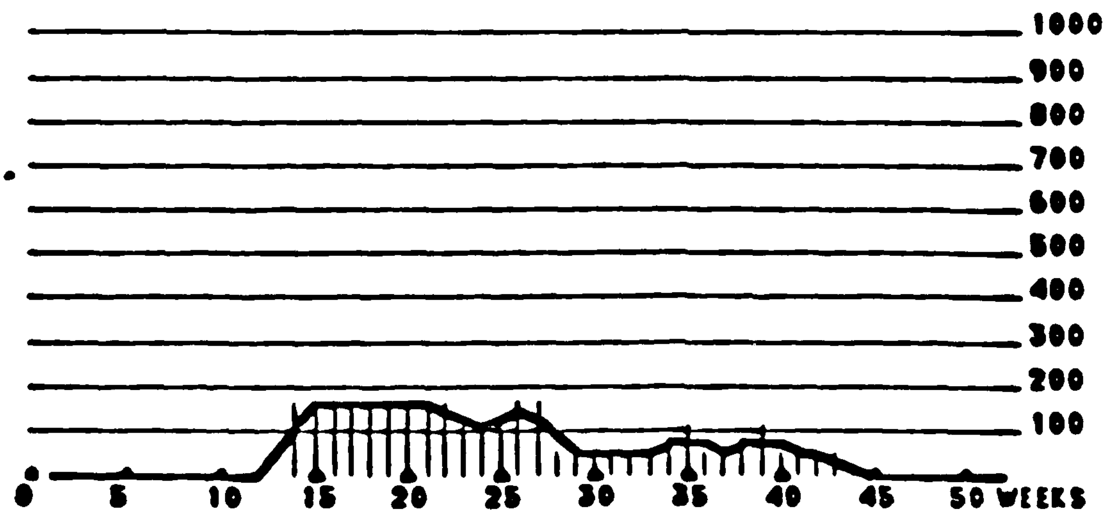
TEAM TRAINER



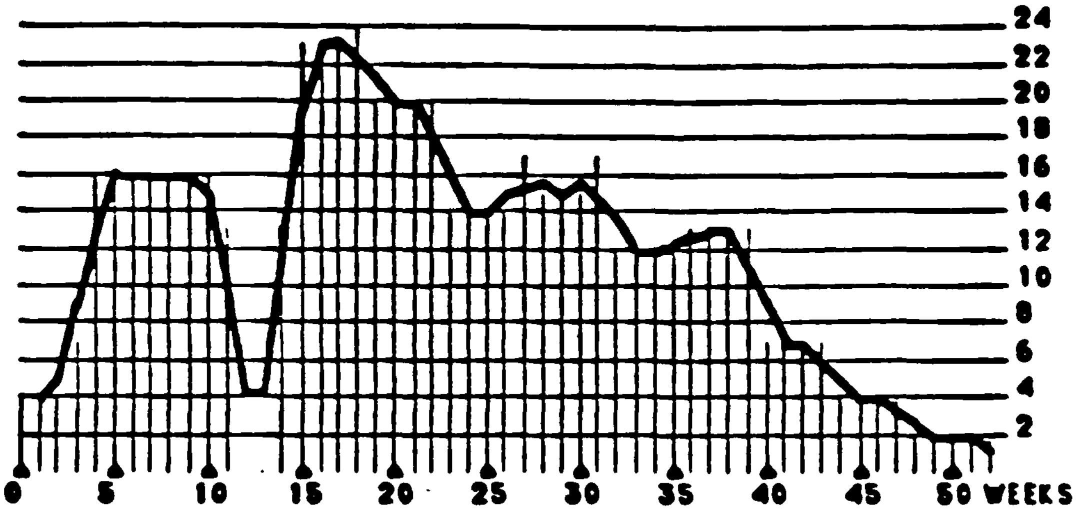
SCAT FLYING HOURS



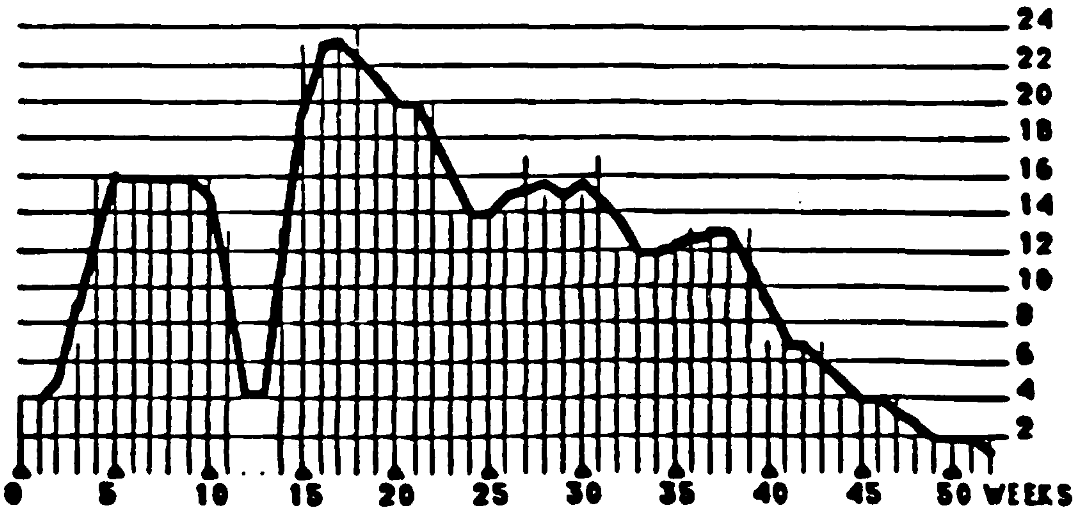
UTILITY FLYING HOURS



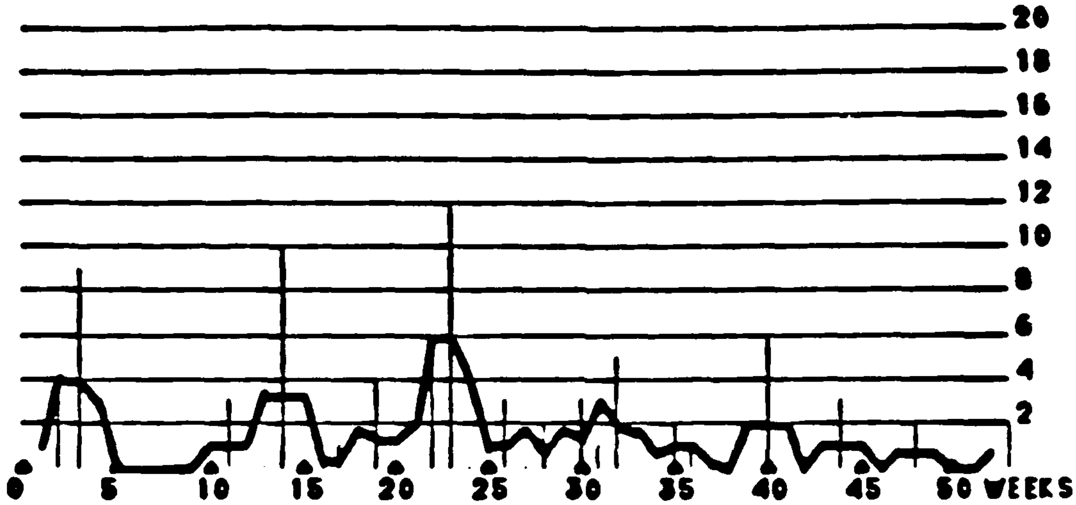
EXTERNAL AIRCRAFT



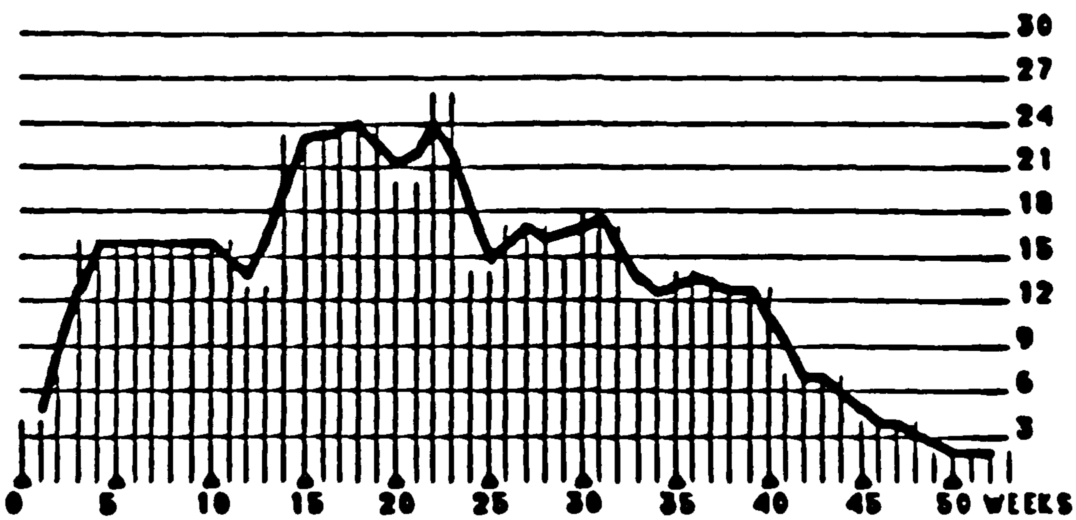
EXTERNAL TOE EQUIPMENT



ADMINISTRATIVE

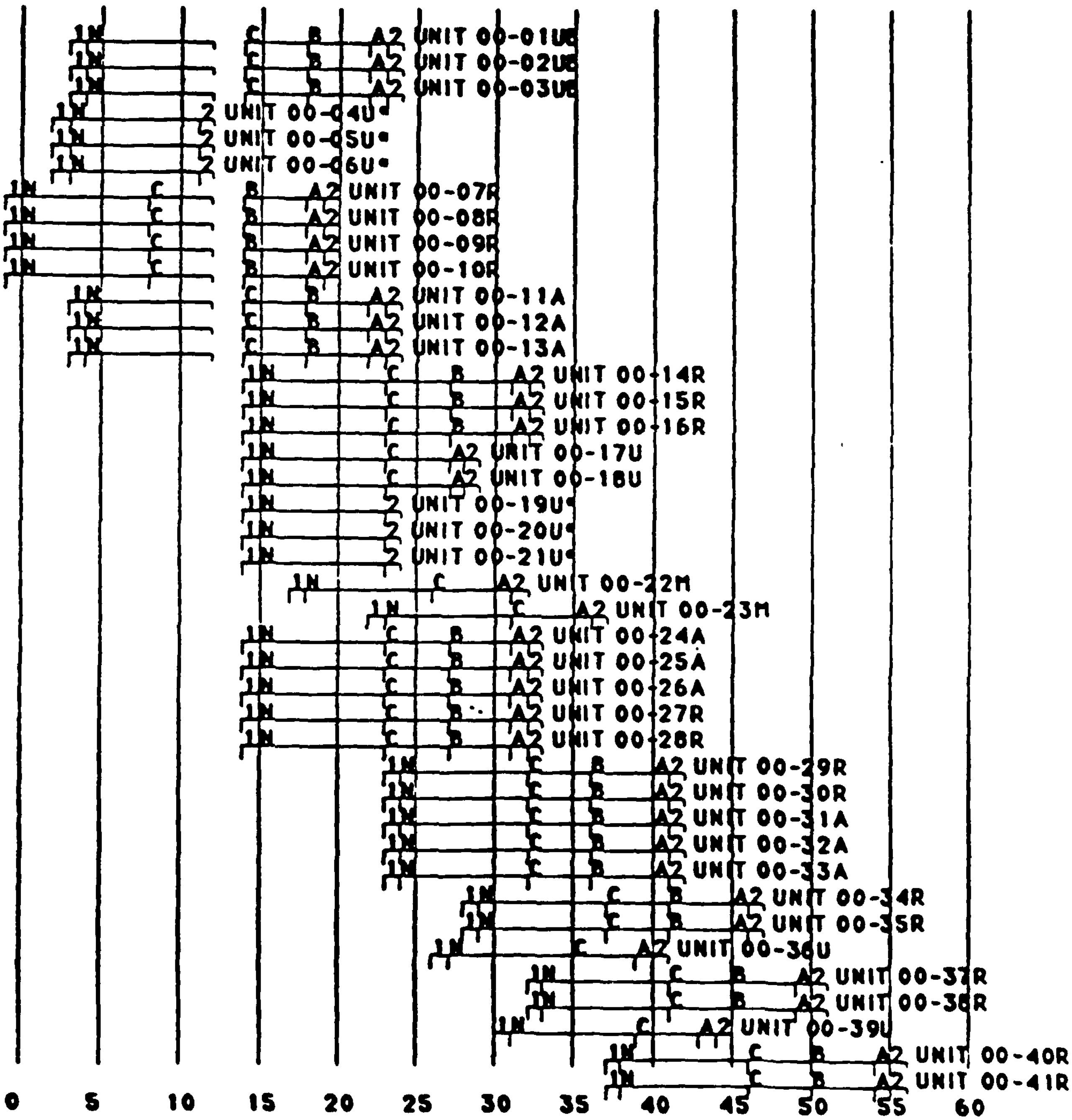


DOWNTIME



TRAINING ALTERNATIVE 2
DECONFLICTED

TRAINING SCHEDULE



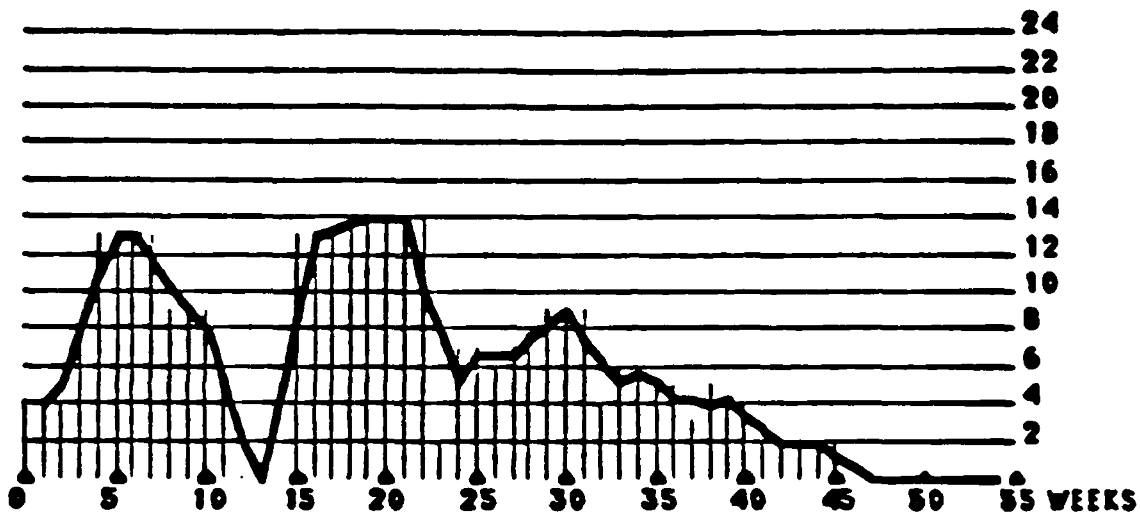
UNIT TRAINING TIMES

Unit	Week Start	Week End	Duration In Weeks
UNIT 00-01UB	3	24	21
UNIT 00-02UB	3	24	21
UNIT 00-03UB	3	24	21
UNIT 00-04U*	2	12	10
UNIT 00-05U*	2	12	10
UNIT 00-06U*	2	12	10
UNIT 00-07R	-1	20	21
UNIT 00-08R	-1	20	21
UNIT 00-09R	-1	20	21
UNIT 00-10R	-1	20	21
UNIT 00-11A	3	24	21
UNIT 00-12A	3	24	21
UNIT 00-13A	3	24	21
UNIT 00-14R	14	33	19
UNIT 00-15R	14	33	19
UNIT 00-16R	14	33	19
UNIT 00-17U	14	29	15
UNIT 00-18U	14	29	15
UNIT 00-19U*	14	24	10
UNIT 00-20U*	14	24	10
UNIT 00-21U*	14	24	10
UNIT 00-22M	17	32	15
UNIT 00-23M	22	37	15
UNIT 00-24A	14	33	19
UNIT 00-25A	14	33	19
UNIT 00-26A	14	33	19
UNIT 00-27R	14	33	19
UNIT 00-28R	14	33	19
UNIT 00-29R	23	42	19
UNIT 00-30R	23	42	19
UNIT 00-31A	23	42	19
UNIT 00-32A	23	42	19
UNIT 00-33A	23	42	19
UNIT 00-34R	28	47	19
UNIT 00-35R	28	47	19
UNIT 00-36U	26	41	15
UNIT 00-37R	32	51	19
UNIT 00-38R	32	51	19
UNIT 00-39U	30	45	15
UNIT 00-40R	37	56	19
UNIT 00-41R	37	56	19

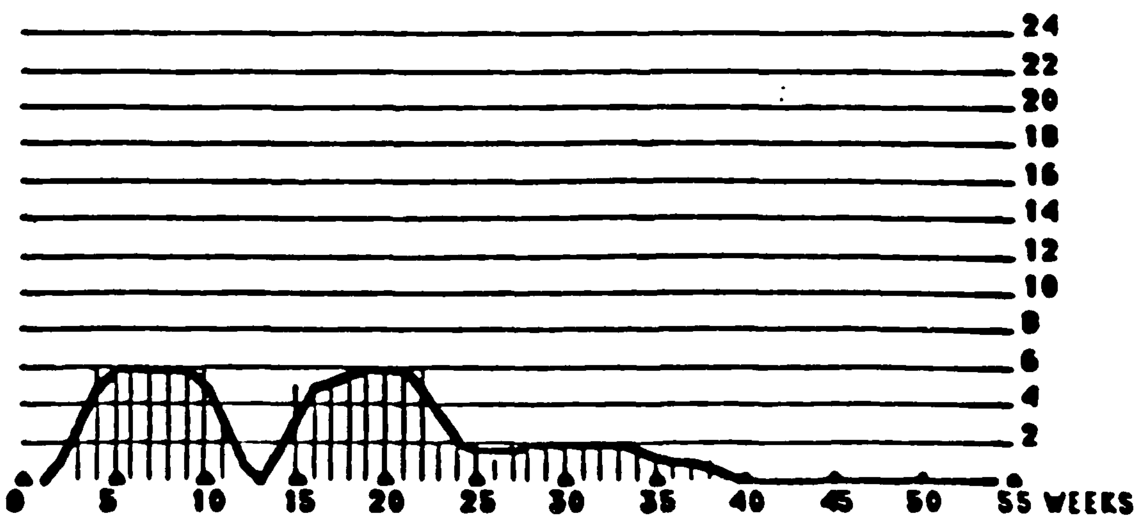
Average Unit Readiness Downtime is 17.6 weeks
Average time to new equipment readiness is 32.4 weeks

CRITICAL RESOURCE DISTRIBUTION FOR TRAINING ALTERNATIVE 2 (DECONFLICTED)

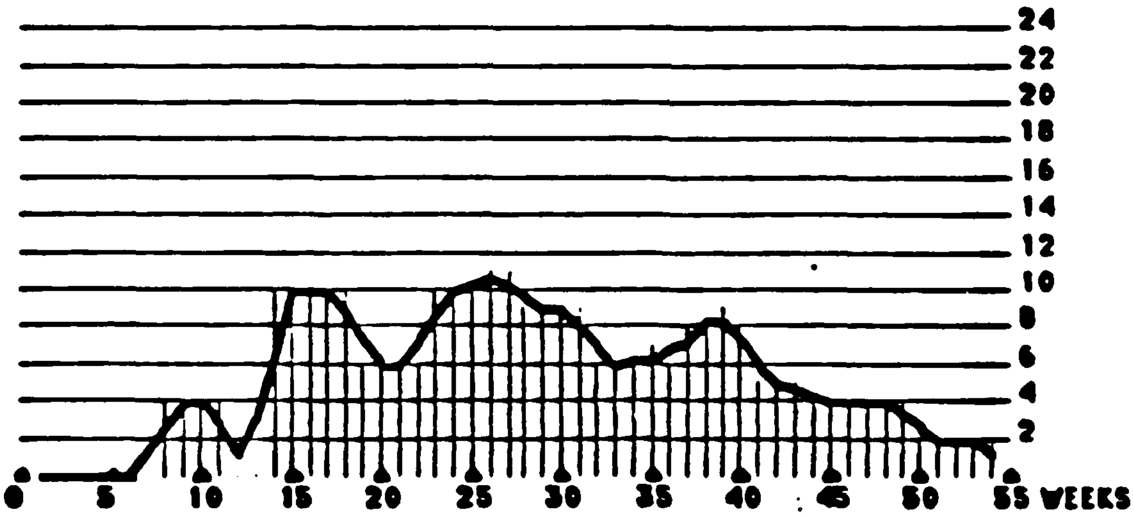
AERIAL GUNNERY RANGE



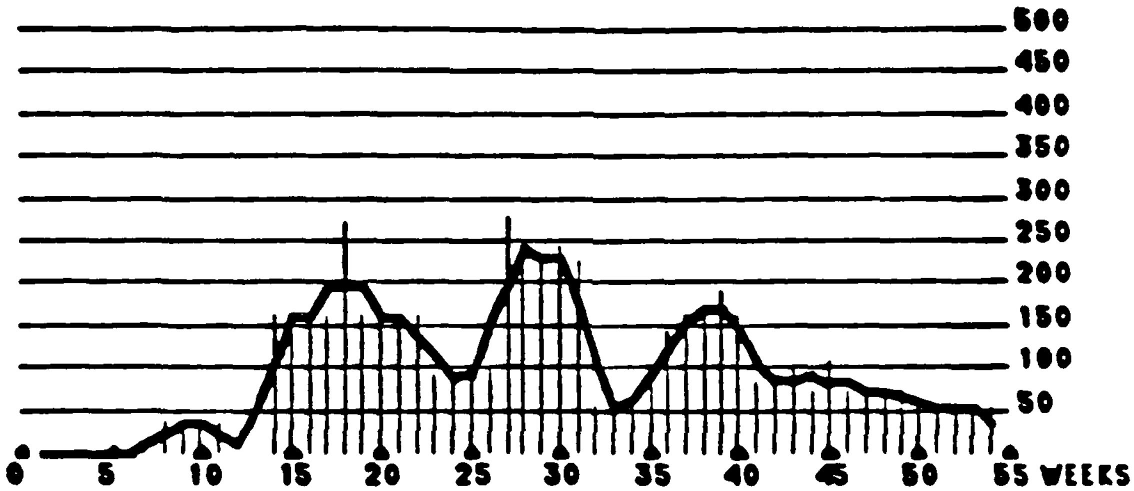
DOOR GUNNERY RANGE



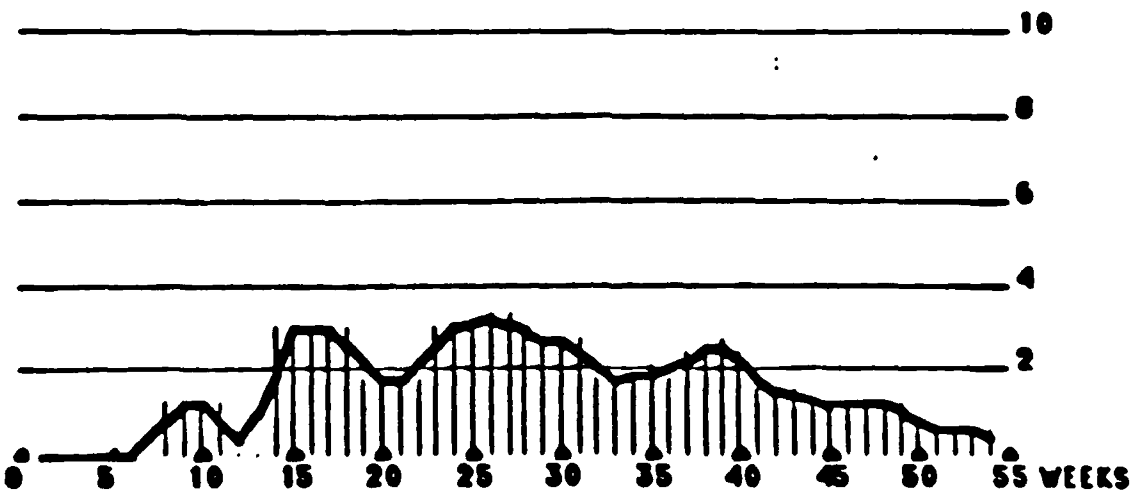
MANEUVER AREA



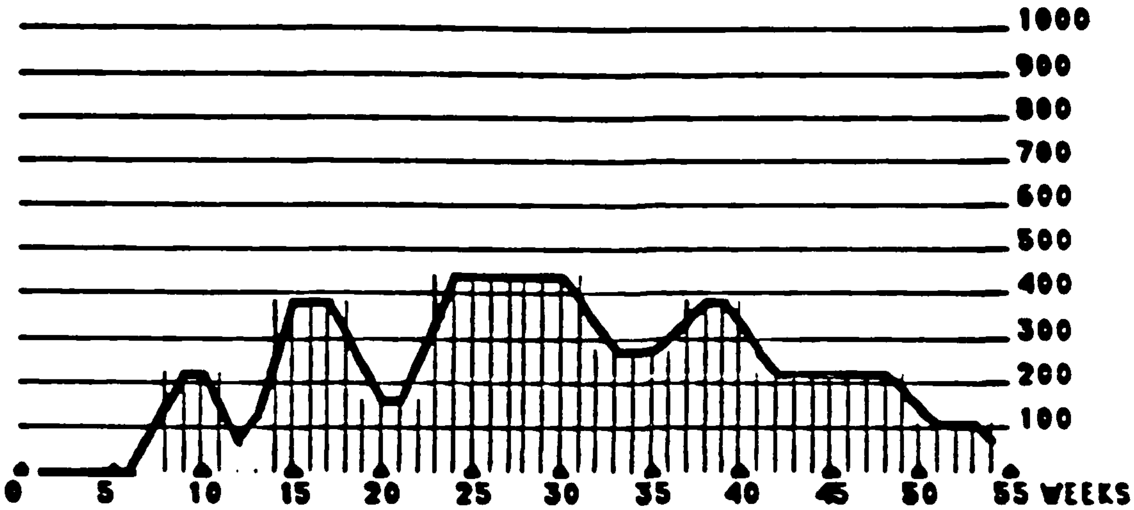
OPFOR



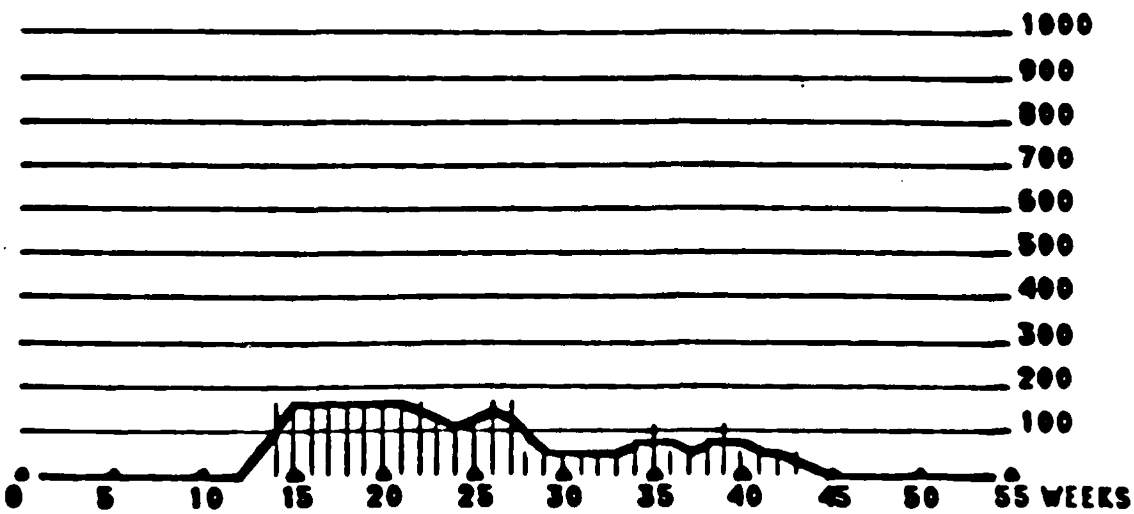
TEAM TRAINER



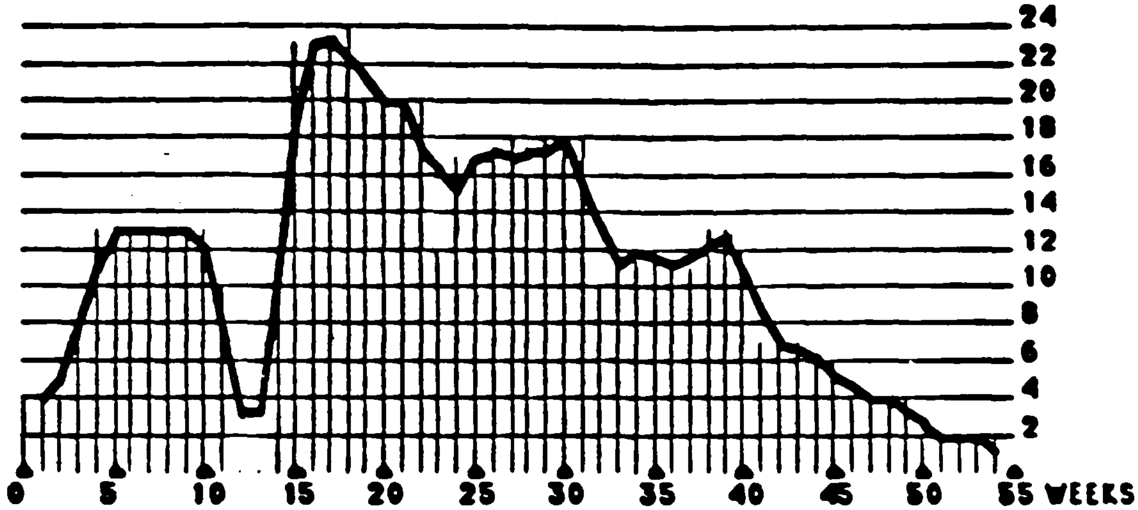
SCAT FLYING HOURS



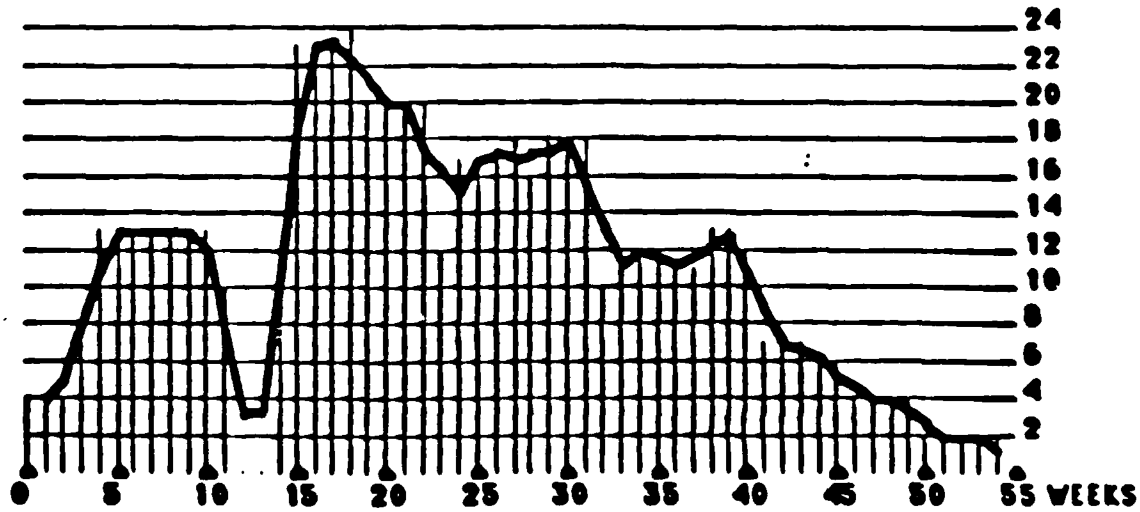
UTILITY FLYING HOURS



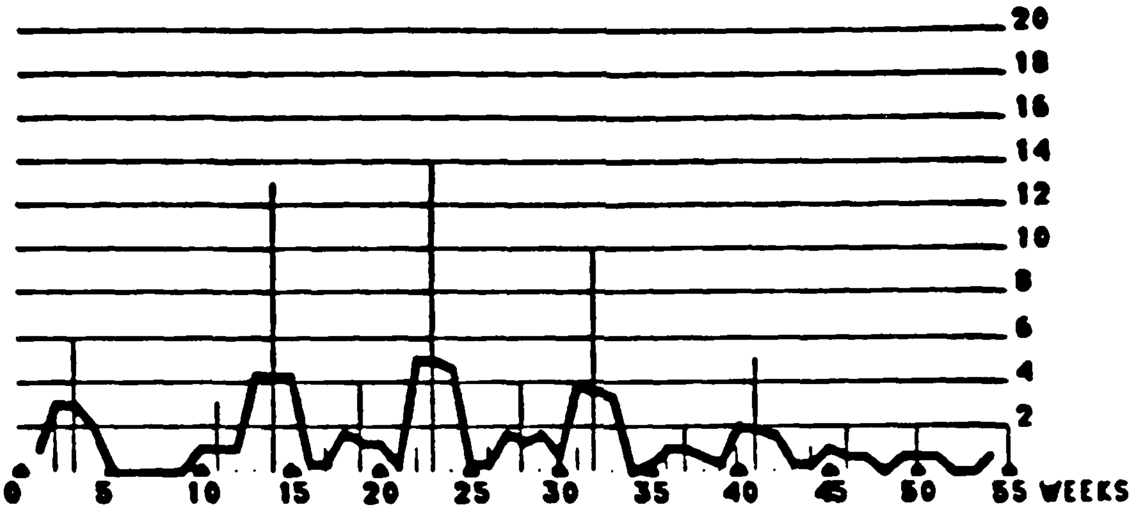
EXTERNAL AIRCRAFT



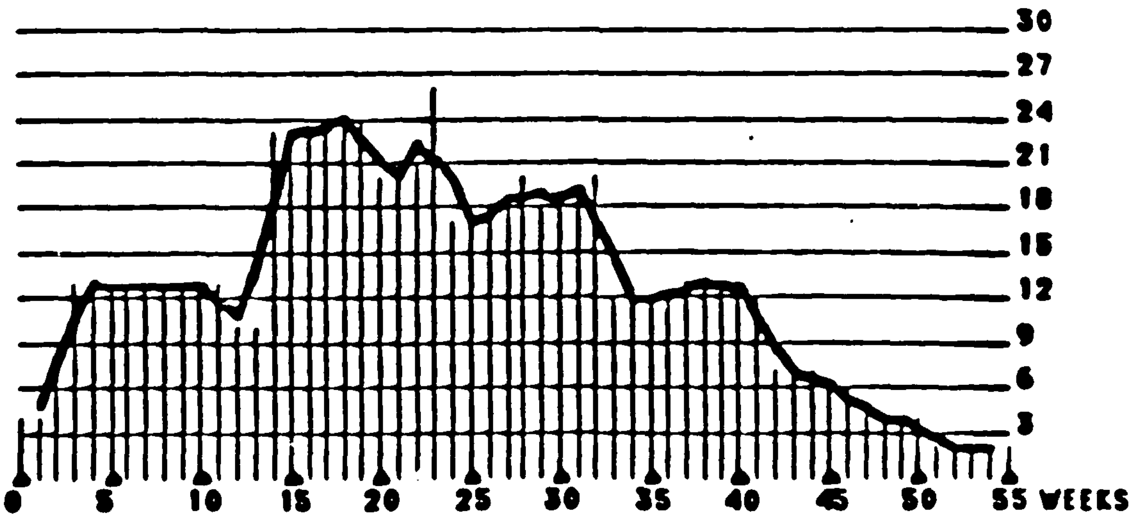
EXTERNAL TOE EQUIPMENT



ADMINISTRATIVE

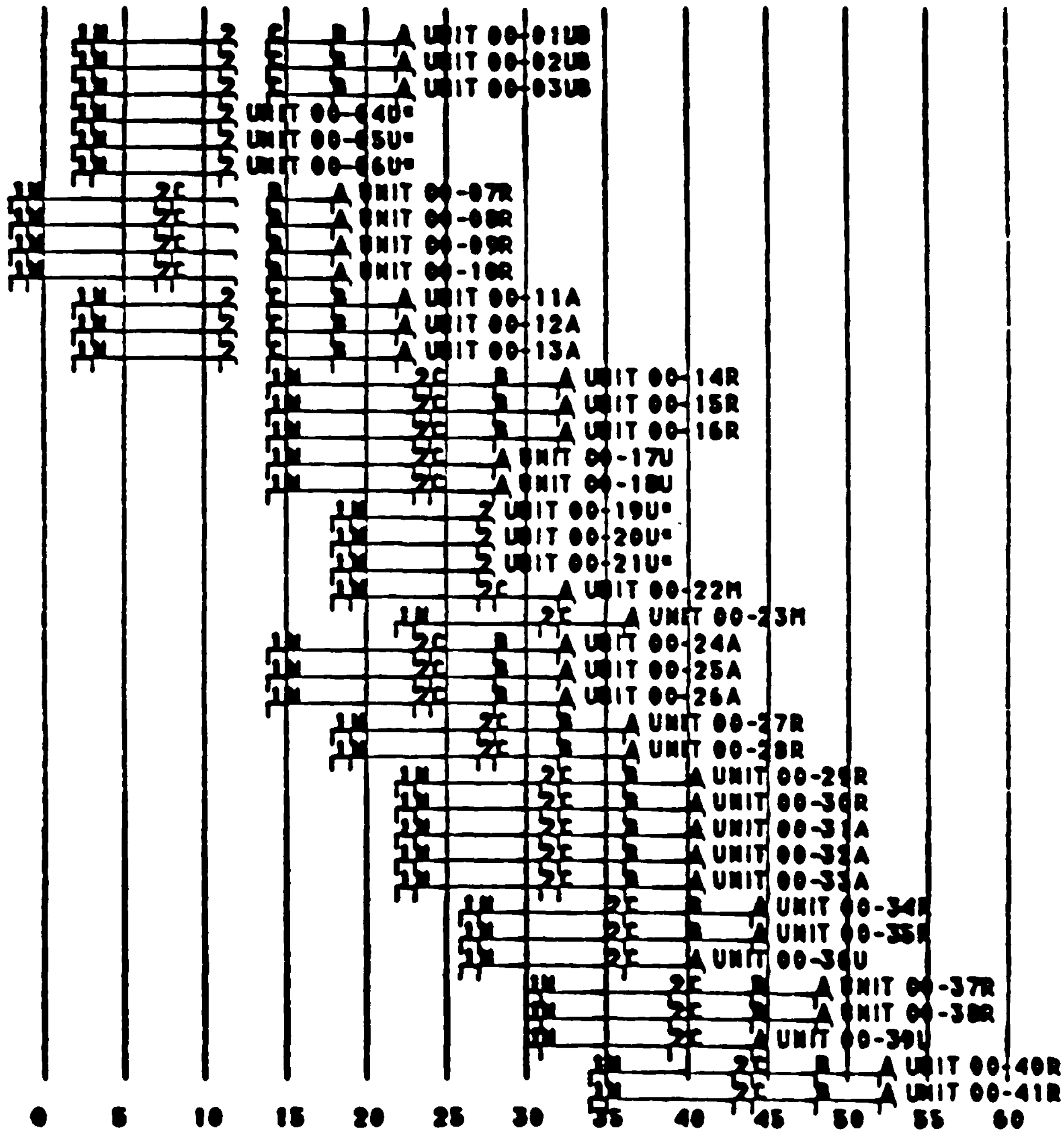


DOWNTIME



TRAINING ALTERNATIVE 3

TRAINING SCHEDULE

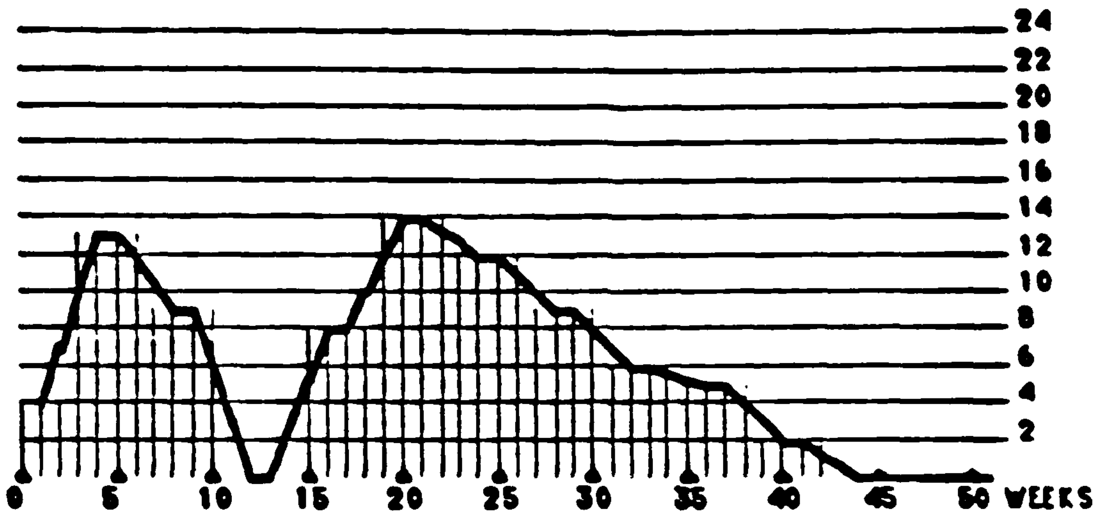


UNIT TRAINING TIMES

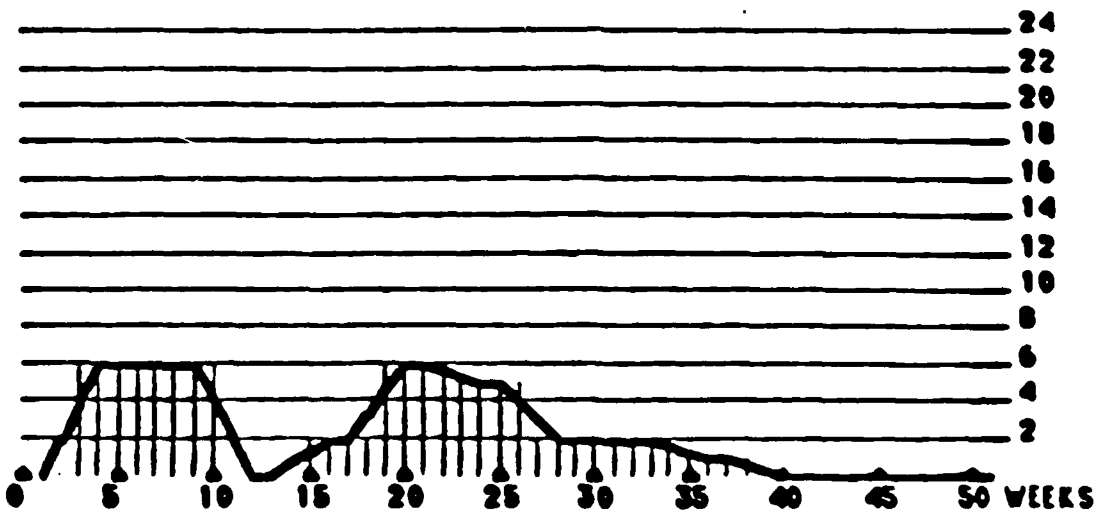
Unit	Week Start	Week End	Duration In Weeks
UNIT 00-01UB	2	23	21
UNIT 00-02UB	2	23	21
UNIT 00-03UB	2	23	21
UNIT 00-04U*	2	12	10
UNIT 00-05U*	2	12	10
UNIT 00-06U*	2	12	10
UNIT 00-07R	-2	19	21
UNIT 00-08R	-2	19	21
UNIT 00-09R	-2	19	21
UNIT 00-10R	-2	19	21
UNIT 00-11A	2	23	21
UNIT 00-12A	2	23	21
UNIT 00-13A	2	23	21
UNIT 00-14R	14	33	19
UNIT 00-15R	14	33	19
UNIT 00-16R	14	33	19
UNIT 00-17U	14	29	15
UNIT 00-18U	14	29	15
UNIT 00-19U*	18	28	10
UNIT 00-20U*	18	28	10
UNIT 00-21U*	18	28	10
UNIT 00-22M	18	33	15
UNIT 00-23M	22	37	15
UNIT 00-24A	14	33	19
UNIT 00-25A	14	33	19
UNIT 00-26A	14	33	19
UNIT 00-27R	18	37	19
UNIT 00-28R	18	37	19
UNIT 00-29R	22	41	19
UNIT 00-30R	22	41	19
UNIT 00-31A	22	41	19
UNIT 00-32A	22	41	19
UNIT 00-33A	22	41	19
UNIT 00-34R	26	45	19
UNIT 00-35R	26	45	19
UNIT 00-36U	26	41	15
UNIT 00-37R	30	49	19
UNIT 00-38R	30	49	19
UNIT 00-39U	30	45	15
UNIT 00-40R	34	53	19
UNIT 00-41R	34	53	19

Average Unit Readiness Downtime is 17.6 weeks
Average time to new equipment readiness is 32.2 weeks

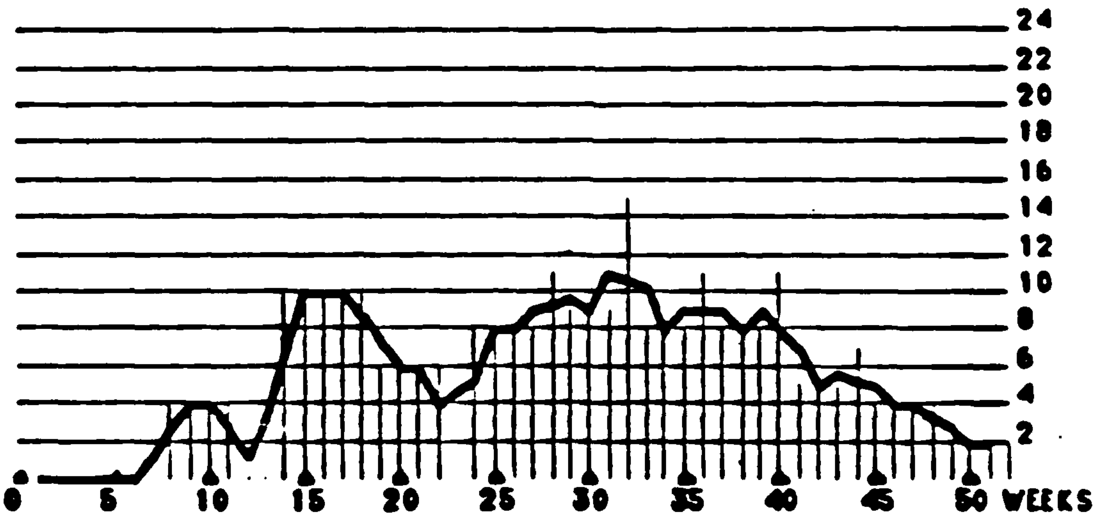
AERIAL GUNNERY RANGE



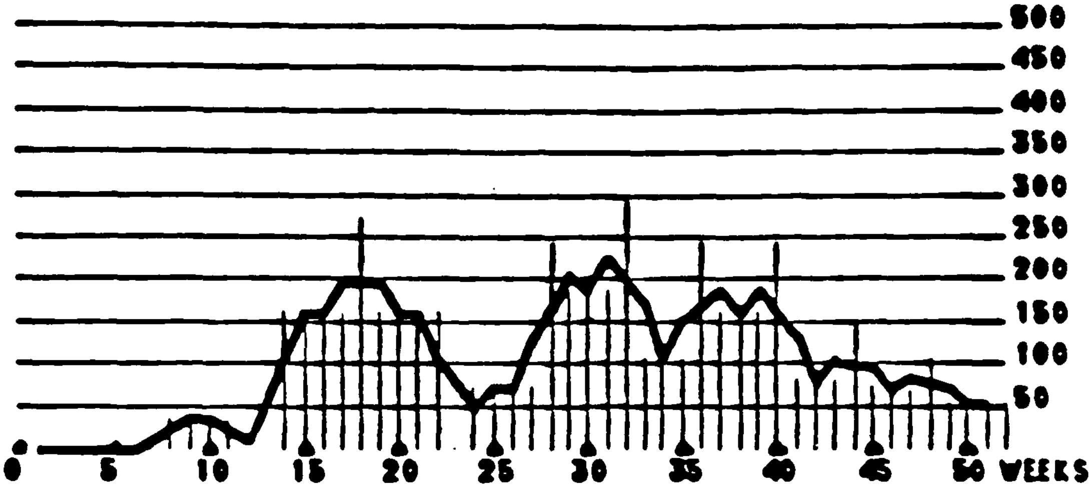
DOOR GUNNERY RANGE



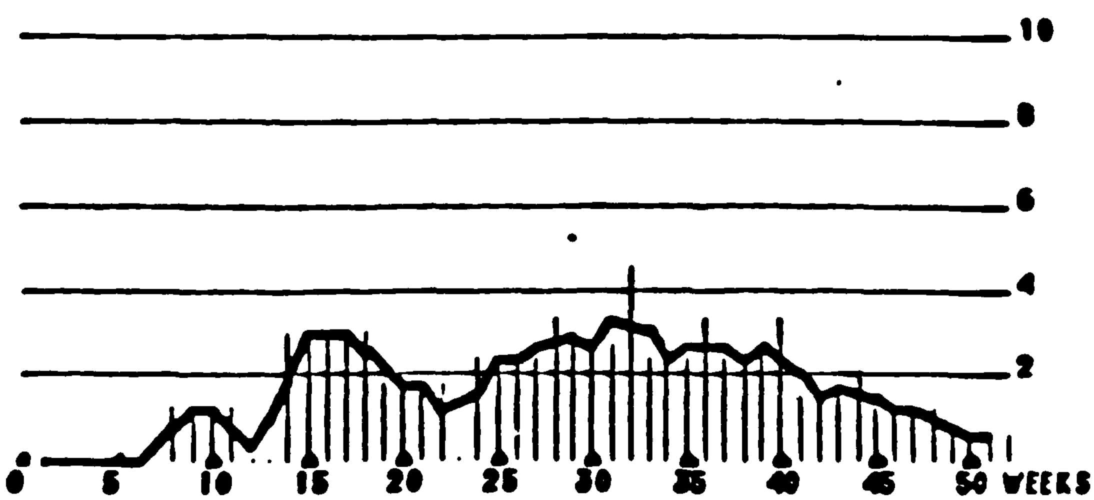
MANEUVER AREA



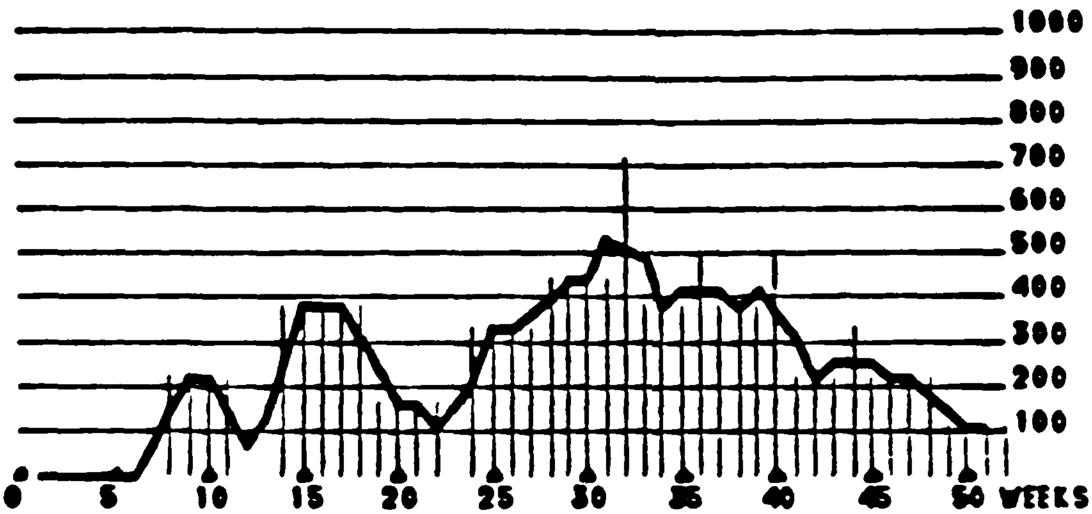
OPFOR



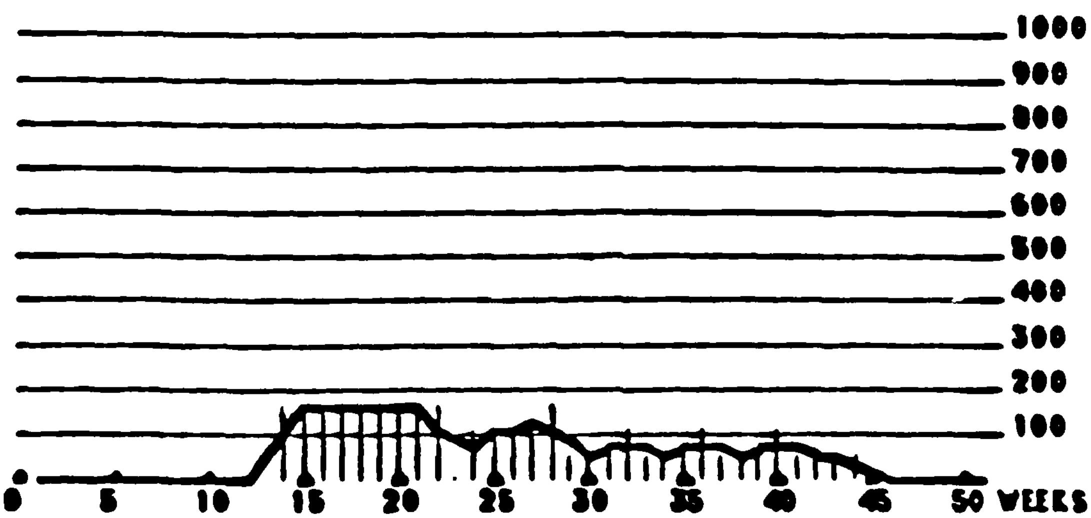
TEAM TRAINER



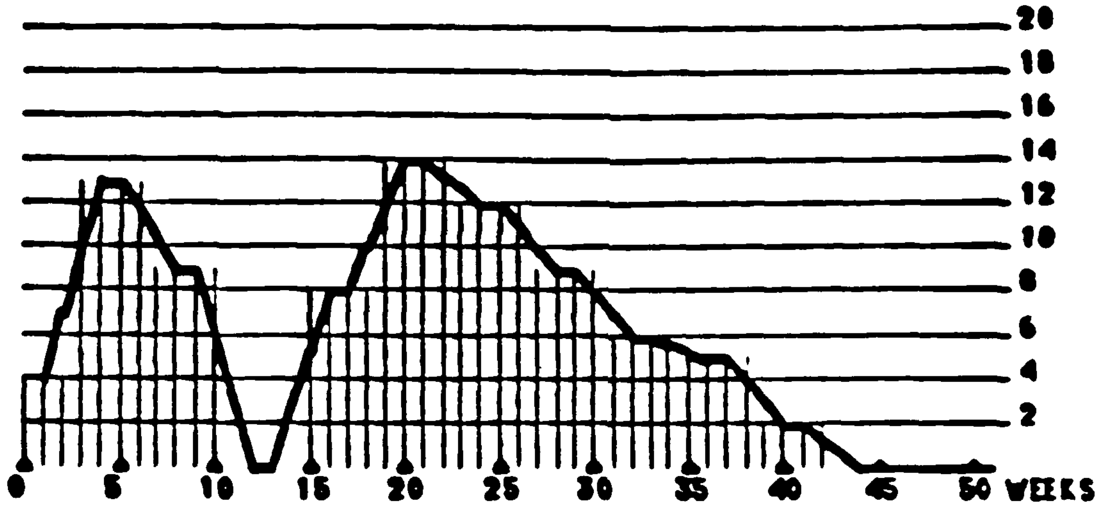
SCAT FLYING HOURS



UTILITY FLYING HOURS



EXTERNAL AIRCRAFT



EXTERNAL TOE EQUIPMENT